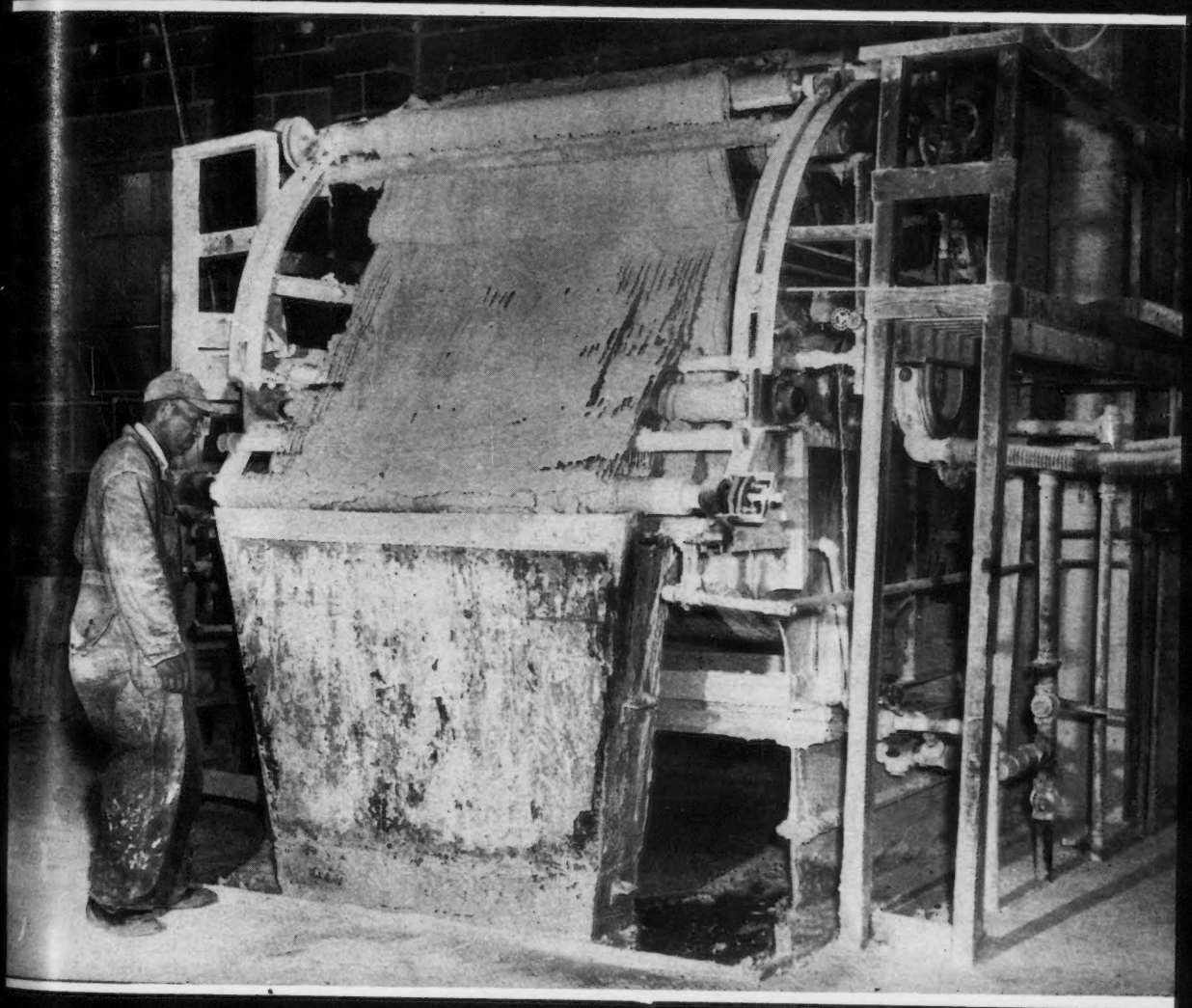
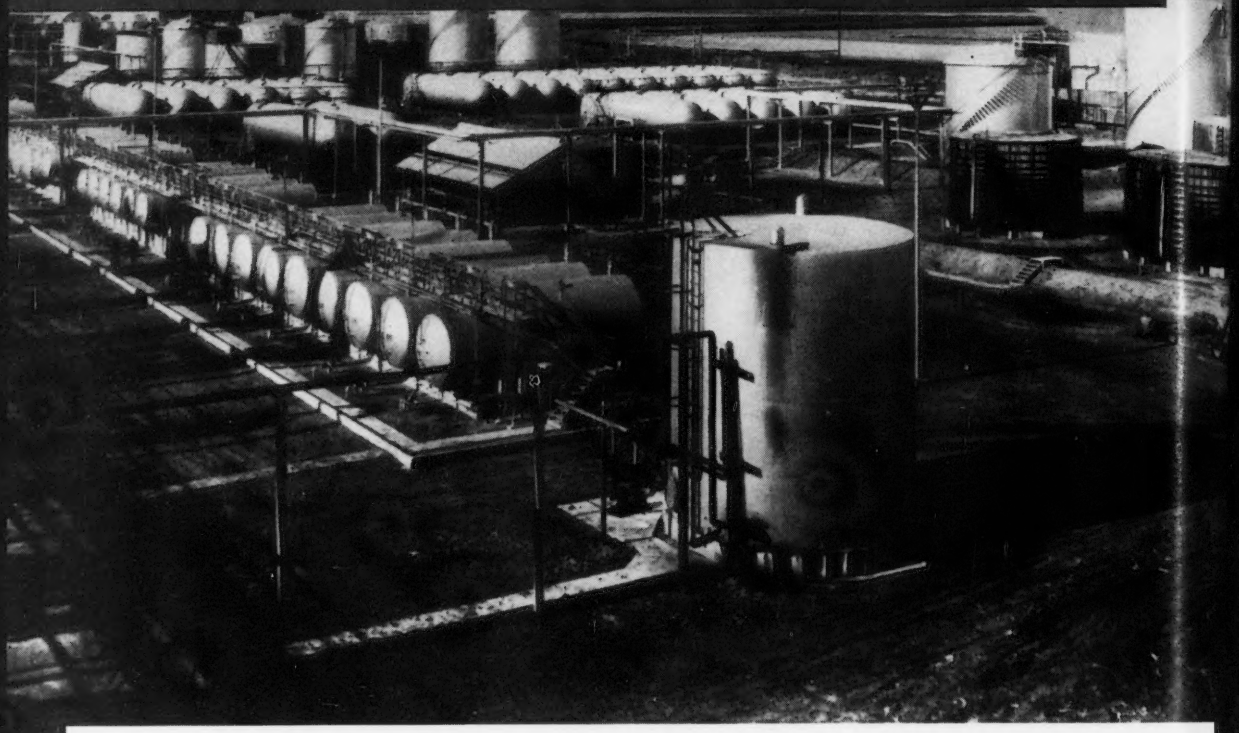
Corrosion



There's more to CORROSION than meets the eye



Sometimes VISIBLE... Often HIDDEN... Corrosion Strikes in Every Plant

This year, American Industry will pay more than $6,000,000,000 for losses created by corrosion... *yet much of this corrosion may never be discovered* until it's too late to protect—and time to pay!

Corrosion is readily detected when it appears as rust layers or failing paint on exposed surfaces. But, by far, the major costs of corrosion come from hidden areas—where only minute inspections and constant care can prevent costly failures.

YOU LOSE IN A "WAITING GAME"

Don't wait for rust or other visible signs to appear. Visible or hidden, corrosion will destroy costly equipment... halt production... cause unnecessary maintenance shutdowns... and contaminate valuable products. Thus, corrosion dips deep into your profits as it creates needless losses totaling thousands of dollars.

YOU CAN PREVENT NEEDLESS WASTE

Check your plant for corrosion's presence. Double-check areas that are vulnerable to *hidden corrosion.* If you would like help, an AMERCOAT Field Engineer will gladly assist you in making a thorough analysis. There is no obligation.

What is AMERCOAT?

AMERCOAT is a method of corrosion control. Not just a single product, but a complete LINE of coatings, individually formulated to solve or control specific industrial corrosion problems.

FOLLOW THE LINE OF *more* RESISTANCE... PROTECT WITH *Amercoat!*

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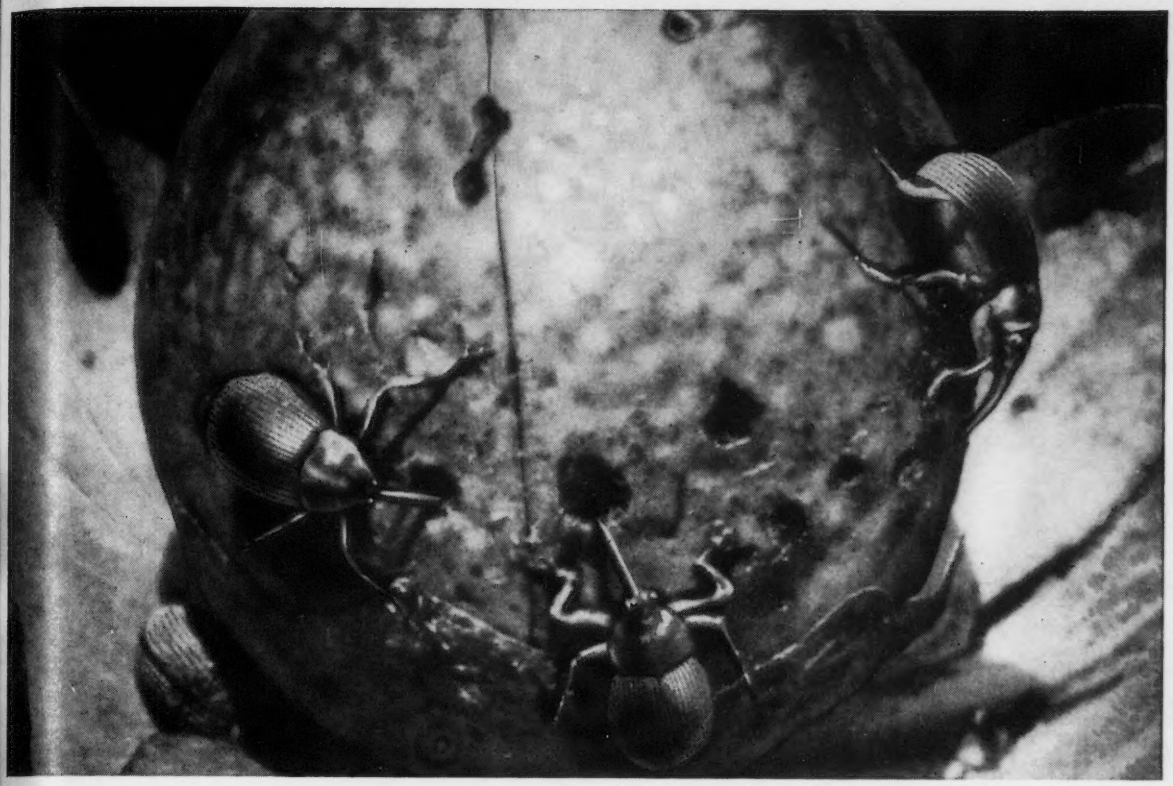

Foiling the beetle with the half-billion bite!

$500,000,000—that's what those little beetles on the cotton plant above cost America in 1950. The boll weevil adds a whopping $10.00 a year to the price every one of us pays for cotton goods. Producing four to five generations a season, the female boll weevil first destroys the flower buds of the cotton plant by laying her eggs in them; later generations deposit their eggs in the cotton bolls, where the greedy grubs raise havoc with the silky cotton fibers. The boll weevil is probably the most destructive of all insect pests, and has forced large agricultural areas to abandon the growing of cotton altogether.

Today our most effective weapon against this pest is the new insecticide BHC (benzene hexachloride). So great is the demand for it that the production of BHC increased 300% last year and now equals or exceeds that of any other insecticide. BHC is produced by the controlled chlorination of benzene by means of a catalyst. Its commercial production is made more difficult by the corrosive qualities of the basic ingredients and the temperatures at which the catalyst operates. To handle these corrosives effectively, processors of this insecticide use many ALOYCO corrosion-resistant valves in the plants where they make BHC. Like the makers of benzene hexachloride, manufacturers of other insecticides such as DDT, Toxaphene, Rotenone, arsenates, and fluorides also depend upon ALOYCO valves for the protection of their products.

ALOYCO valves are supplied in stainless steel and other corrosion-resistant alloys by the Alloy Steel Products Company, Inc., the world's largest specialists in valves for corrosive service. Such concentration has developed a practical knowledge of the chemistry of corrosion, and produced the metallurgical and mechanical know-how to combat it. That's why ALOYCO corrosion-resistant valves are used by many leading firms in the chemical field . . . to handle anything from acetic acid to zirconium tetrachloride.

ALOYCO valves go hand-in-hand with chemical progress.

If corrosives play a part in your business it would pay you to bring your problems of corrosion, contamination, discoloration, or temperature extremes to the *Aloyco Corrosion Engineering Service*. Our engineers and metallurgists will be glad to pre-test various alloys under actual line conditions; our long and diversified experience in this field is available to assist you in selecting the correct valves and alloys to meet your particular requirements. Write us about your own corrosive problems. 3.7

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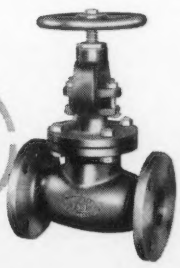
ALOYCO VALVES
1st in Corrosive Service



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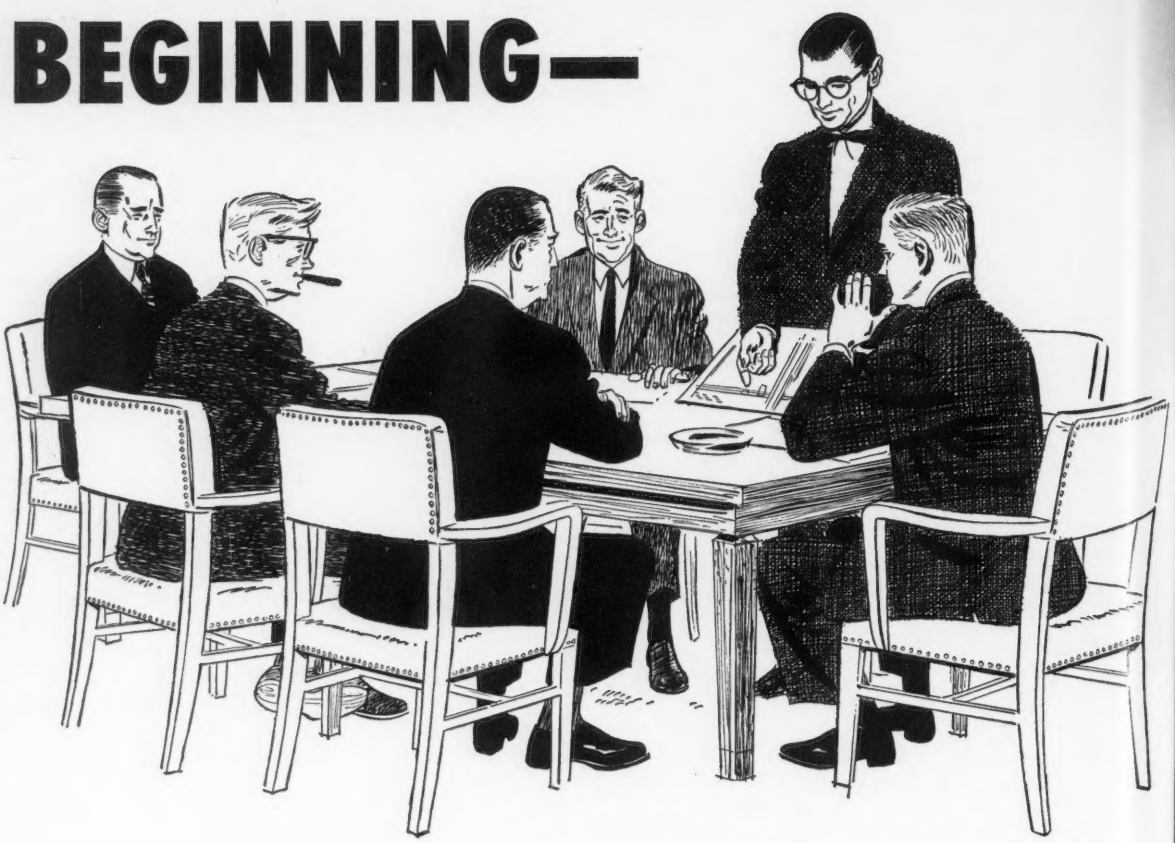

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That's why it's wise, when planning a new pipe line, to include Bitumastic Enamel in your designs, plans and specifications. Bitumastic Enamels, manufactured from selected coal-tars, have proved they can prevent corrosion. Many oil and gas pipe lines that were coated with Bitumastic Enamel and laid 20 and 30 years ago are still in good service today.

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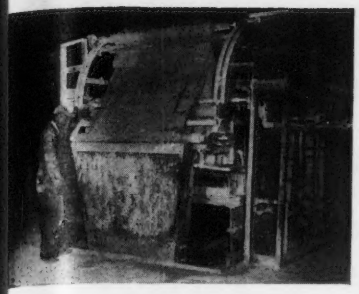

THIS MONTH'S COVER—This rotary vacuum filter press at Foote Mineral Company, Philadelphia, is extracting caustic solution from waste solids. The Dynel filter cloth used outlasted other materials it replaced. Dynel, tested in 50 percent concentrations of sodium hydroxide and 28 percent concentrations of ammonium hydroxide suffered only 6 percent loss of strength and no other physical changes. The material is made by Textile Fibers Dept., Carbide and Carbon Chemicals Co., 30 East 42nd St., New York 17, N. Y.

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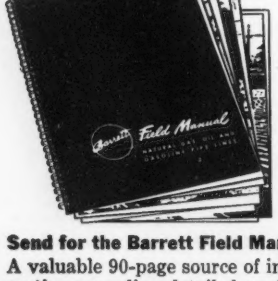

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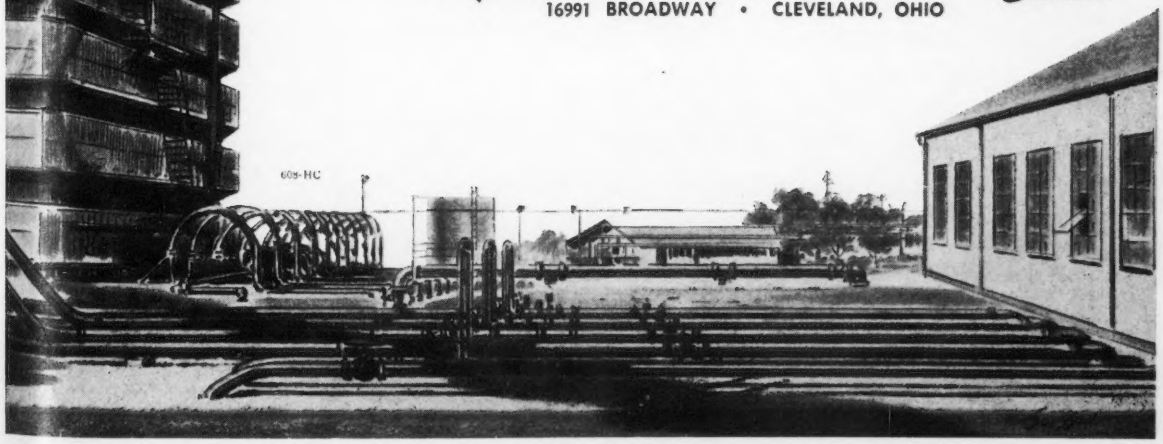

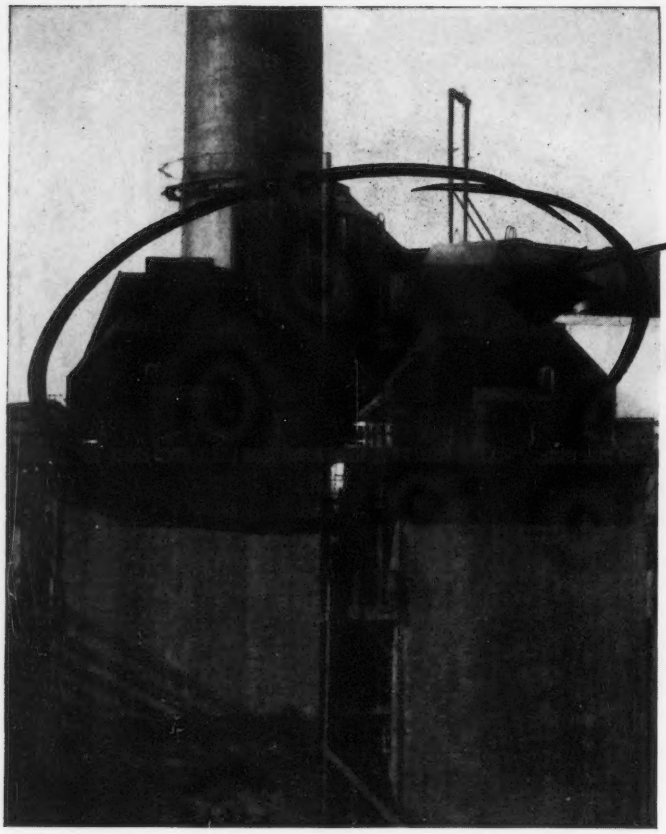

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(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

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Corrosion

OFFICIAL MONTHLY PUBLICATION

National Association of Corrosion Engineers

An Association of Individuals and Organizations Concerned with Control of Corrosion

1061 M & M Building Houston 2, Texas

Vol. 9 March, 1953 No. 3

Report on the Activities of

Technical Practices Committee 7— *Materials for Use at High Temperatures*

By M. A. SCHEIL, Chairman*

TECHNICAL Practices Committee 7 has for the past two years been active in a study of the behavior of both metallic and non-metallic materials which are in application or are being considered for application in environments where sustained temperatures of above 400 degrees F are encountered.

The committee members have reviewed existing literature and have had the opportunity to use private information in a high temperature corrosion compilation.

The data has now been prepared in chart form which will present to the user of the data an idea of what materials might be used at a prescribed lower limit and those which would be unsuitable when a certain temperature was exceeded.

On the information that has been presented it is evident that much further information will be required before indicating the best materials to be used at temperatures above 400 degrees F.

It is also evident that a survey of this type cannot adequately cover such added influences as surges, contaminants, stresses and so forth. However, where information has been available the tables will code such effects as stress cracking, intergranular corrosion and pitting.

In a tabulation of this type it was decided not to include rates of corrosion because of the difficulty of providing adequate descriptions of the surrounding circumstances that may sometimes influence the extent of damage. Therefore the data are bracketed as low, moderate and high corrosion rates.

It is planned that the high temperature corrosion compilation will be issued as a NACE Report this year.

It is the hope of the committee that the NACE membership will cooperate in expanding the information to be given in this report.

* Director of Metallurgical Research, A. O. Smith Corp., Milwaukee, Wis.

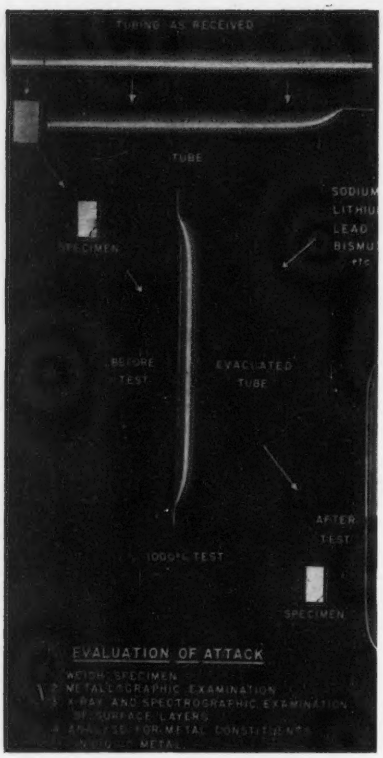

Figure 1—Static corrosion testing. Tubulating technique. Schematic diagram illustrating technique used to contain test specimen in static liquid metal corrosion test.

Abstract

In many instances, liquid metal corrosion is simply a question of solubility rate and extent of solubility. However, solubility and diffusion barriers may be developed from the components or impurities in the form of intermetallic compounds, metal oxides, nitrides and other surface films. This paper does not discuss in detail the desirability or formation of these films, but recognizes their existence and discusses the nature and extent of interaction between a variety of metals of relatively high melting point and low melting metals which are arbitrarily referred to as "liquid metals." Such metals and alloys are those which melt below 400 or 500 degrees Centigrade.

When a liquid metal comes in contact with a solid metal, a certain degree of interaction occurs. Since alloys may behave in a different fashion from pure metals, the paper discusses the behavior of each at some length, giving specific examples for each. Photomicrographs show results.

A thorough evaluation of a material under study for use in a given liquid metal should include a study of: 1. Dimensional changes; 2. Weight changes; 3. Changes in composition of the liquid metal; 4. Change in the chemical composition of the metal surface by chemical or spectrographic analysis; 5. Changes in crystal structure of metal surface by x-ray or electron diffraction; 6. Determination of nature and depth of attack by metallographic study; and 7. It is advisable sometimes to determine hardness changes or gradient to supplement the metallographic study.

Liquid Metal Corrosion★

*By ANTON de S. BRASUNAS**

CORROSION may be defined as destruction by chemical or electrochemical agencies in contrast to erosion which means destruction by mechanical agencies." This definition[1] obviously embraces the attack of solid metals by liquid metals, and as such, the term "Liquid Metal Corrosion" is considered to be appropriate.

In many instances, liquid metal corrosion is simply a question of solubility rate and extent of solubility. However, solubility and diffusion barriers may be developed from the components or impurities in the form of intermetallic compounds, metal oxides, nitrides and other surface films. It is not the purpose of this article to discuss in detail the desirability or formation of these films, but merely to 1) recognize their existence and 2) discuss the nature and extent of interaction between a variety of metals of relatively high melting point and low melting metals which are arbitrarily referred to as "liquid metals." Such metals and alloys are those which melt below 400 or 500 degrees C.

The use of liquid metals will increase as the technology of their behavior is better understood. Some general data relative to the suitability of various commercial metals and alloys for use in liquid metals appears in the Liquid Metals Handbook.[2] Much work is presently being initiated to expand the limited state of knowledge in this field. This article is intended to acquaint new experimenters in this field with the varied nature of attack which has been observed in corrosion studies at the Oak Ridge National Laboratory at temperatures of approximately 1000 degrees C (1832 degrees F).

A static liquid metal corrosion test simply involves the interaction of a solid metal specimen with a liquid metal for a suitable length of time at a desired temperature. An evaluation of the extent and nature of the resulting interaction would then determine one important characteristic which is vital in determining the suitability of a given solid metal for use in the particular liquid metal environment.

However, numerous complications arise in attempting to set up the ideal system described above and these may introduce appreciable sources of error. Interfering side reactions may be caused by:

1) Impurities and non-homogeneity in the solid metal specimen,
2) Impurities in the liquid metal,
3) The improbability of obtaining and maintaining a completely inert ambient (both container and atmosphere are major problems),

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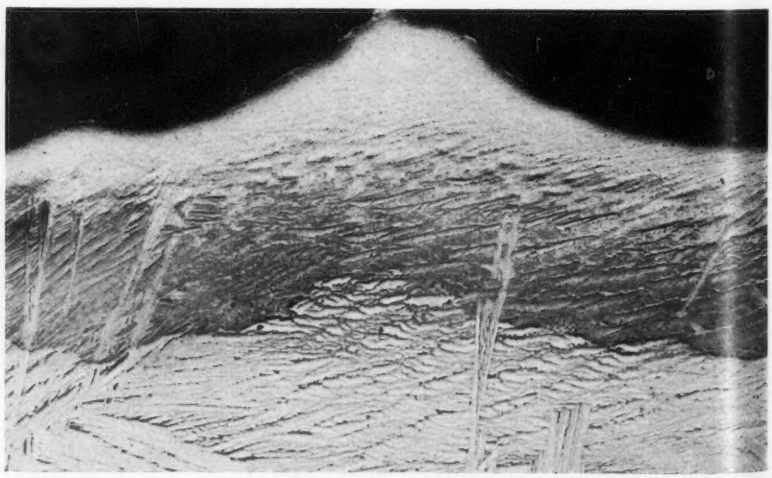

Figure 2—Type Ia. Uniform solution from surface of titanium after a 40-hour exposure to lead at 1000 degrees C (1832 degrees F). 100X.

4) Temperature fluctuations or temperature gradients,
5) The probability of having the specimen in a non-ideal condition; i.e., residual stresses, unstable grain size, and the exposed crystallographic faces may undergo alteration with accompanying physical changes of the specimen.

Interference from some of the above complicating conditions, however, can be minimized by employing more refined testing techniques so that reliable and consistent results can be obtained.

Apparatus

The apparatus used in making liquid metal corrosion tests at ORNL consisted of ordinary laboratory furnaces controlled to give a minimum in thermal gradient and cycling about the mean test temperature. Early tests were subject to appreciable thermal gradients and cycling of about 10 degrees F about the mean test temperature. More recent improvements in furnace control and design have given no perceptible gradients and cycling of about one degree Centigrade. Pot furnaces were found to be more suitable than glo-bar or wire wound tubular furnaces in obtaining a minimum of temperature gradients, especially if the pot were filled with a conducting medium, such as lead.

A good dry box technique is important in minimizing the amounts of impurities sealed into the metal containers. A gas tight system involving a vacuum pump and purification unit for the inert gas is vital. However, if rubber gloves are used, a certain amount of contamination is inevitable. Sealing metal capsules without contamination remains as an unsolved problem. A good seam welding technique or heliarc welding in the dry box would be considered to be very satisfactory.

The tests are made in sealed metal tubes which have previously been evacuated. Figure 1 is a schematic diagram illustrating the preparation of a test specimen and container. The tubing was 0.50-inch OD and had a wall thickness of 0.035-inch. The test specimen was prepared from the same tube stock since it was essential that they be of identical composition.

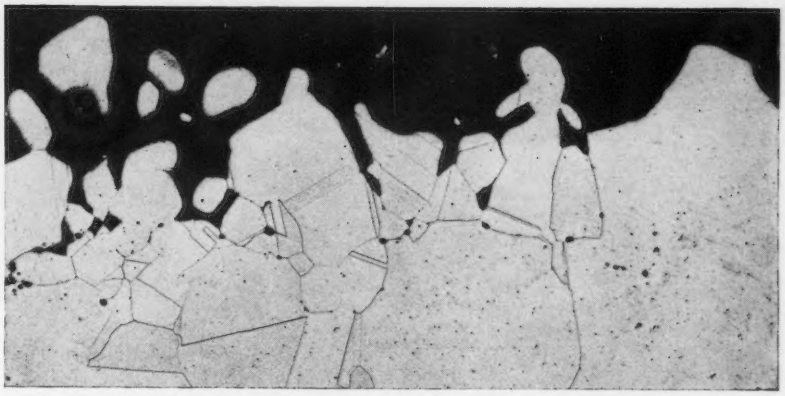

Figure 3—Type Ib. Intergranular solution of nickel by lead at 1000 degrees C. 100X.

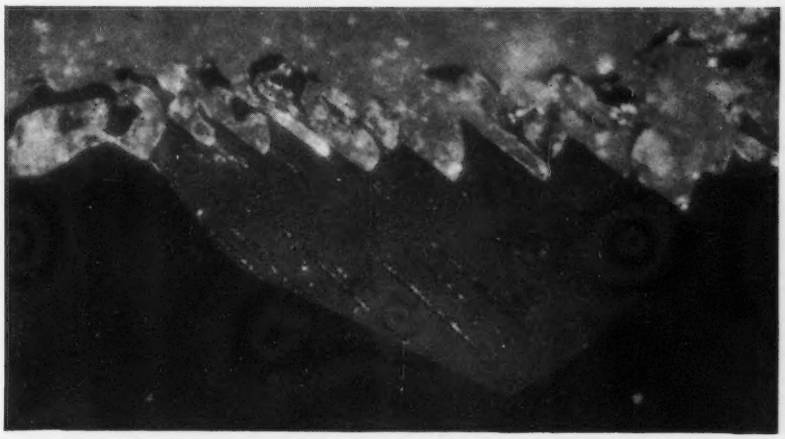

Figure 4—Type Ic. Crystalline facet development on beryllium surface caused by solution into lead at 1000 degrees C. Polarized light. 250X.

Figure 5—Type II. Evidence of sodium penetration inward shown by precipitation of Cu-Na grain boundary phase in OFHC copper after 100-hour exposure to sodium at 1000 degrees C. 500X.

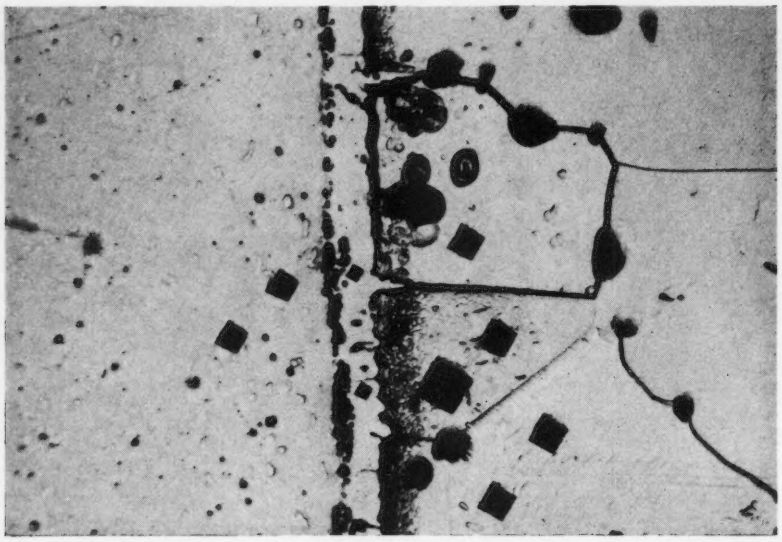

Figure 6—Type III. Intermetallic phase formed on vanadium (left) after 100-hour immersion in lead (right) at 100 degrees C. 200X.

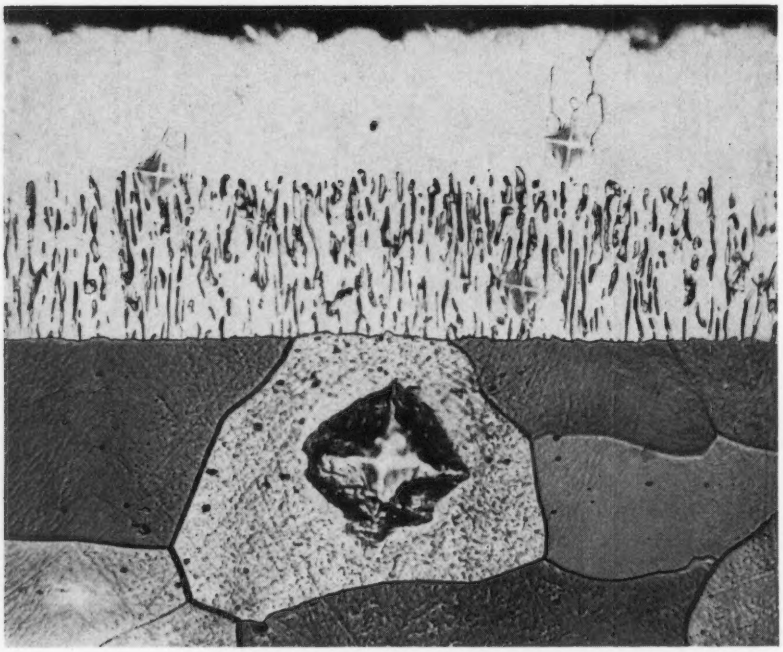

Figure 7—Type IVa. Isothermal mass transfer of nickel on molybdenum caused by presence of dissimilar metals in contact with molten sodium at 1000 degrees C for 100 hours. 1000X.

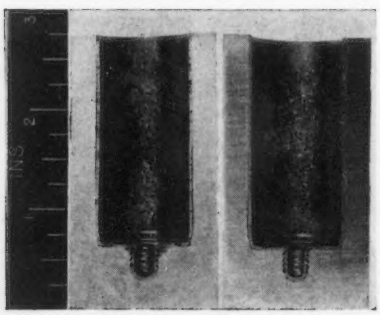

Figure 8—Type IVa. Isothermal mass transfer of silicon on iron caused by dissimilar metals in contact with molten lithium at 1000 degrees C for four hours.

After crimping and heliarc welding one end, the tube was annealed in purified hydrogen to relieve stresses and reduce surface oxide. Liquid metal and a specimen was then inserted into the tube in a dry box and sealed.

The exposure is then made at a suitable temperature for any desired time and then quenched to room temperature and examined.

Types of Corrosive Attack

When a liquid metal comes into contact with a solid metal, a certain degree of interaction occurs. The extent of such interaction generally increases with increasing temperature. Because alloys may behave in a different fashion from pure metals, it may be convenient to list the different types separately as follows:

In the case of a pure metal:

Type I. Solution of solid metal into the liquid metal
- a) uniform solution
- b) intergranular solution, or penetration of liquid metal into grain boundaries because of surface tension phenomena
- c) crystalline facet development caused by different solution rates in variout crystal directions.

Type II. Diffusion of liquid metal atoms into solid metal lattice; this may or may not result in a phase transformation. (Alloying).
- a) uniformly
- b) intergranularly

Type III. Formation of an intermetallic layer on the surface

Type IV. Mass transfer
- a) isothermal mass transfer caused by composition gradients
- b) thermal gradient mass transfer
- c) energy gradient mass transfer; reorientation of surface contour to one of lower energy state.

In the case of alloys, the following additional types of corrosion may occur:

Type V. One alloy constituent may be leached from the surface of the alloy because of selective solution. This can result in phase transformations and/or subsurface voids within the grains or along grain boundaries.

Type VI. Subsurface precipitation of an intermetallic compound caused by the inward diffusion of liquid metal atoms and interaction with one or more of the alloy components.

In the case of impurities:

Type VII. If impurities are present (it is almost impossible to exclude them entirely), this may form simple or complex substances on the metal surface or in the liquid metal which may stimulate or suppress interaction (oxides and nitrides have been frequently detected on the metal surface).

A series of photomicrographs is shown which illustrate some of the types of attack described. Uniform solution (Type Ia) is illustrated in Figure 2 which shows the surface of titanium after a 40-hour exposure to lead at 1000 degrees C (1832 degrees F). This would result in a significant weight loss and decrease in specimen dimensions, but metal-

lographically will show practically no evidence of attack, other than a somewhat wavy surface contour as shown.

Intergranular attack (Type Ib) is well illustrated in Figure 3 by the attack of lead on nickel at 1000 degrees C. The development of crystal facets (Type Ic) is shown in Figure 4; this is a beryllium specimen which had been exposed to molten lead.

The diffusion of a liquid metal into a solid metal (Type II) was encountered when sodium was contained in a copper (OFHC grade) capsule at 1000 degrees C. A section of the capsule revealed a blue-gray grain boundary constituent, which is shown in Figure 5. The entire cross section of the copper specimen was embrittled as evidenced by a simple bend test. The formation of an intermetallic compound on the surface (Type III) was observed when vanadium was immersed in molten lead at 1000 degrees C for 100 hours. This is shown in Figure 6.

Isothermal mass transfer (Type IVa) may be illustrated by Figures 7 and 8. The former shows the deposition of nickel from the nickel container to a molybdenum specimen in an early experiment and the latter illustrates a reverse situation; i.e., the deposition of material from the specimen to the container walls. The undesirability of such phenomena in corrosion testing cannot be over-emphasized. Dissimilar metals should therefore be avoided unless fully understood and recognized to be compatible. Thermal gradient mass transfer (Type IVb) is shown as Figures 9 and 10. This can present a very serious problem in a piping system; the hot end may be dissolved excessively resulting in a puncture, or the crystalline deposit in the cold end may obstruct the tube passage. In corrosion testing this phenomenon represents an abnormal situation which, if present, invalidates the test results. A simple explanation for this behavior logically assumes a variation in solubility with temperature wherein supersaturation and deposition is encountered at colder areas and undersaturation and solution is experienced at hotter areas. Energy gradient mass transfer (Type IVc) may be illustrated by Figures 11 and 12. Such action merely redistributes mass to a more stable configuration and is not accompanied by any perceptible weight change whatsoever.

Figure 9—Type IVb. Thermal-gradient mass transfer of metal from hot areas to cool areas on the container walls, caused by temperature gradients in the system. 4X.

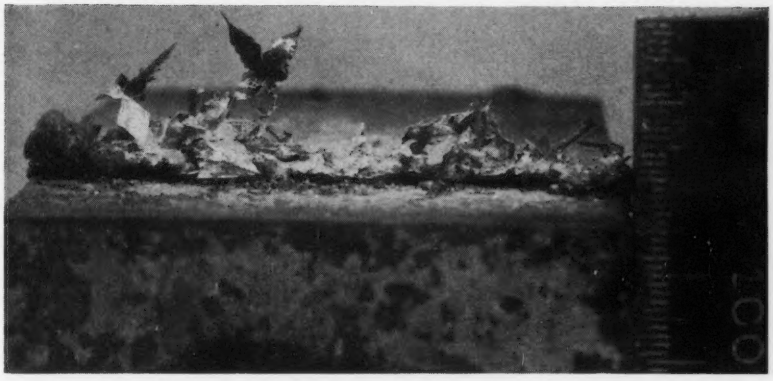

Figure 10—Type IVb. Thermal gradient mass transfer of metal to the specimen; crystals represent solution from hotter areas. 3X.

The leaching of one constituent from a Type 304 stainless steel alloy (Type V) is shown in Figure 13. In this case, it is believed that nickel was leached from the surface and grain boundary of the specimen. Because of the reduced nickel content, the face-centered-cubic (austenitic) phase would therefore be unstable and transformation to the body-centered cubic (ferritic) phase would occur. Figure 14 is a similar situation in a more advanced stage of leaching; here the removal of nickel has occurred to a greater depth and cavities may be seen in the transformed areas.

Evidence of inward penetration of liquid metal atoms to cause precipitation (Type VI) has been noted in the case of sodium (Figure 15) and lead (Figure 16). The hardness of the gray particles shown in Figure 16 was appreciably greater than that of the ferrite matrix, indicating that these are certainly not lead but an intermetallic particle.

The formation of chromium oxide films on chromium-bearing alloys and nitride films on zirconium specimens has been detected by x-ray diffraction (Type VII). These compounds undoubtedly can be attributed to impurities which are practically impossible to eliminate completely. Their presence can certainly exert an appreciable influence on the rate of attack.

It is quite probable that any corrosive attack actually encountered

would be a complex combination of several of these types. In most cases, simple gravimetric determinations of weight gain or weight loss are entirely unsatisfactory as a method of determining the damage sustained; other methods must be used.

Furthermore, changes in physical and mechanical properties will obviously accompany changes in chemical composition and physical structure of the surface region caused by corrosion. These may take the form of reduced ductility, loss in strength, or susceptibility to possible notch brittleness and these cannot be measured easily. It is therefore impossible to evaluate properly the seriousness of the damage caused by the various forms of corrosive attack without first reviewing the purpose of the metal member and the demands made upon it for mechanical strength, rigidity and other mechanical properties.

The use of corrosion data obtained in static tests performed under carefully controlled isothermal conditions cannot be used directly to predict liquid metal-solid metal compatibility under dynamic conditions in a practical application. The only reliable way to determine the extent of corrosion that would occur in a given dynamic system having a fixed thermal gradient and using metals in certain combinations, would be to actually make a test in an identical dynamic system using the temperature gradients and metal combinations anticipated. Extrapolation of corrosion data under one set of conditions for predicting behavior under other conditions may be very misleading and should be done, if at all, by qualified personnel who are aware of its shortcomings.

Figure 11—Type IVc. Energy gradient mass transfer illustrated by polycrystalline 316 stainless steel alloy in sodium for 400 hours at 1000 degrees C. Note development of crystallographic planes only on certain grains. 250X.

Evaluation of Degree of Corrosion

The quantitative determination of the extent of corrosion has always been a problem to persons engaged in corrosion research. The liquid metal corrosion field is particularly difficult in this respect and deserves careful study. Even a casual glance at the types of corrosive attack illustrated in the previous section should be sufficient to indicate that conventional weight change measurements are not only unsatisfactory, but can actually be misleading. Weight loss measurements would be valid only in the instance of Type Ia attack where uniform solution has occurred. Weight change measurements of

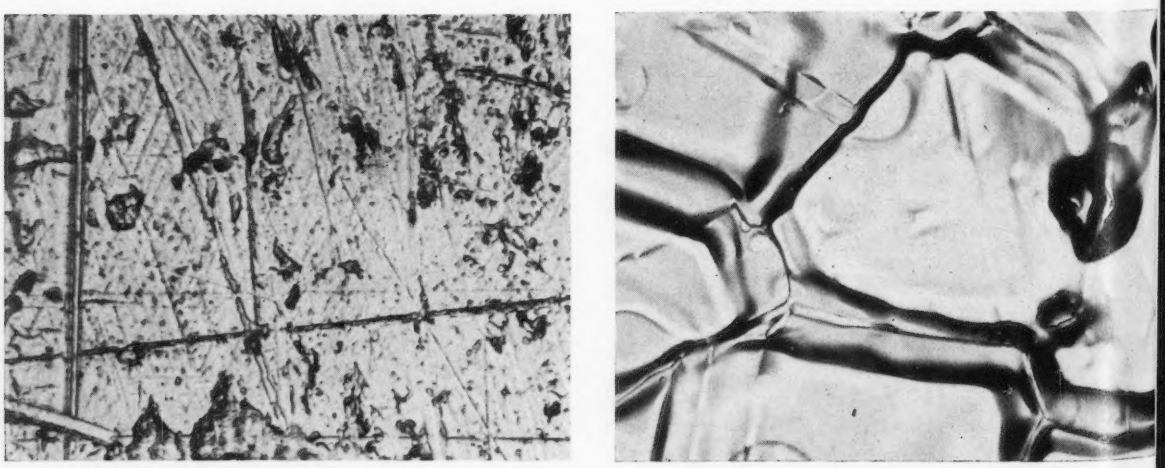

Figure 12—Type IVc. Energy gradient mass transfer on 80 Ni-20 Cr alloy showing original surface of specimen (left) and surface after 40-hour exposure (right) to sodium at 1000 degrees C. No weight change was detected. 75X.

intergranularly attacked specimens would be incapable of indicating the depth of such attack and metallographic examination must be employed. Furthermore, weight gain determinations, when surface films are formed or when inward diffusion occurs, cannot be properly interpreted. Such complex reactions cannot be adequately described by simple gravimetric units, or converted into an average corrosion rate expressed in terms of inches penetration per year or milligrams per square decimeter per day.

A thorough evaluation of the material under study for use in a given liquid metal should include a study of the following:

1. Dimensional changes of the specimen.
2. Weight changes of the specimen.
3. Changes in composition of the liquid metal.
4. Changes in the chemical composition of the metal surface by chemical or spectrographic analysis.
5. Changes in crystal structure of metal surface by x-ray or electron diffraction.
6. Determination of nature and depth of attack by careful metallographic study. That is the most important tool for use in determining the extent and nature of attack.
7. In some cases, it may also be advisable to determine hardness changes or gradients to supplement the metallographic study. Crude bend tests are often useful to determine possible embrittlement of the material.

Many laboratories are not equipped to make a very thorough analysis as described above and must resort to a partial study. In this case, the writer strongly urges that major emphasis be placed on metallographic examination and very little, if any, on gravimetric measurements.

Acknowledgments

The writer acknowledges the splendid metallographic work done by the group under R. J. Gray at ORNL, and to

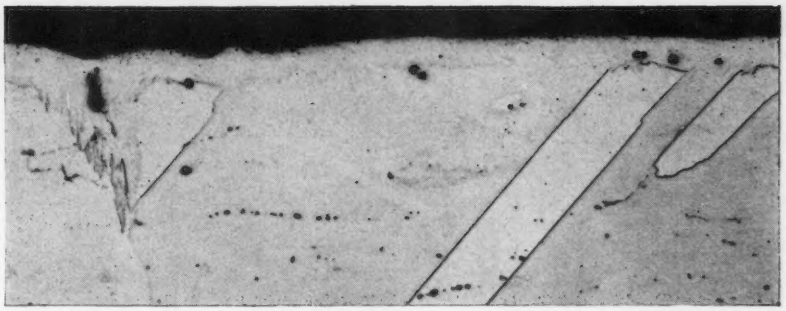

Figure 13—Type V. Leaching of nickel from surface of 304 stainless steel by molten lithium at 1000 degrees C in 40 hours. Note gamma transformation at surface and adjacent grain boundary. 250X.

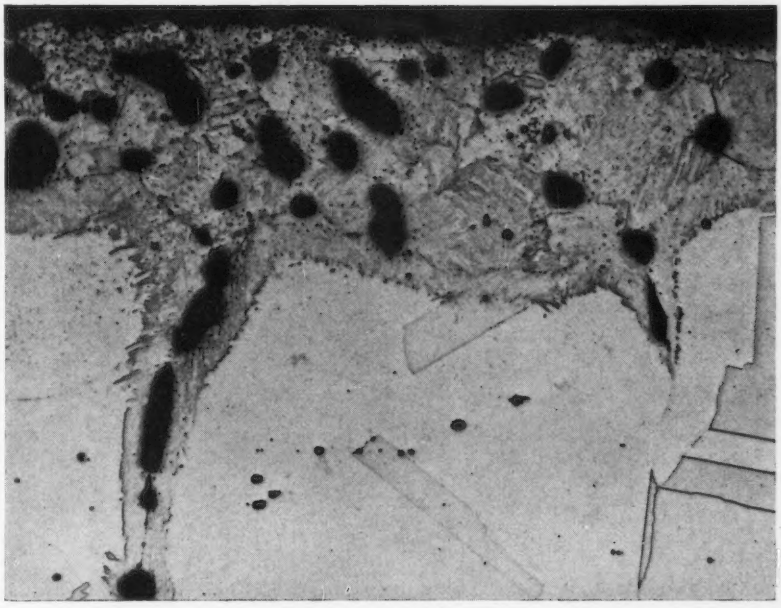

Figure 14—Type V. Advanced stage of leaching on 304 stainless steel by lithium at 1000 degrees C in 400 hours. 250X.

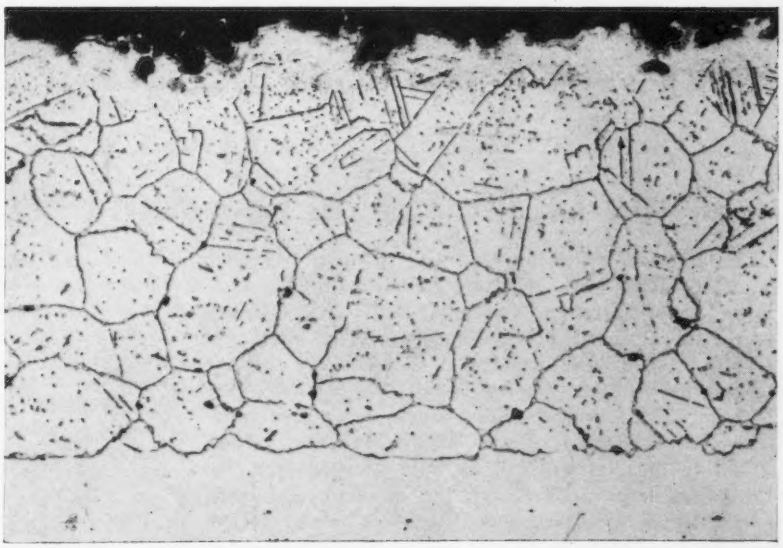

Figure 15—Type VI. Precipitation of unknown phase at surface of 316 stainless steel after 100-hour exposure to sodium at 1000 degrees C.

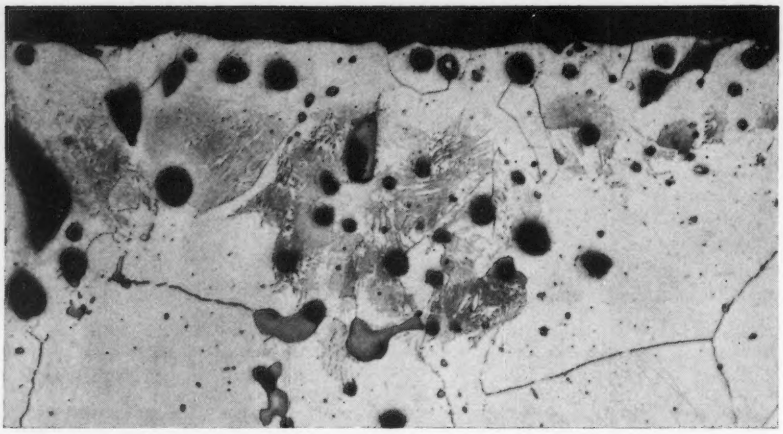

Figure 16—Type VI. Precipitation of lead-containing phase beneath surface of 446 stainless steel after 400-hour exposure to lead at 1000 degrees C. Gray phase is appreciably harder than ferritic matrix. 200X.

members of the Corrosion Group, Mssrs. L. R. Trotter, L. A. Abrams, J. E. Pope and others whose work under the direction of J. E. Cunningham, E. C. Miller, W. D. Manly and the writer is represented here. The permission of the Oak Ridge National Laboratory to publish this article is also gratefully acknowledged. This article has been taken from a more comprehensive ORNL report (classified) on this subject and will be printed soon.

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2. Liquid Metals Handbook. Second Edition, Atomic Energy Commission, Dept of Navy, Washington, D. C. (1952) June. Unclassified.

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Views on the Mechanism of Pitting Corrosion of Aluminum*

By P. M. AZIZ

P. M. AZIZ has worked since 1949 on studies dealing with the mechanism of the corrosion of aluminum, including a year at the Institute for the Study of Metals, University of Chicago where he carried on research on fundamentals of corrosion. He holds a BA Sc in chemical engineering and MA and PhD degrees in physical chemistry from University of Toronto. His thesis dealt with surface tension of aqueous sulfuric acid and transference phenomena in molten salts. He joined the staff of Aluminium Laboratories, Ltd., in 1949.

Abstract

1. Thermodynamic calculations have been carried out to determine the possible corrosion reactions of aluminum in neutral and near neutral aqueous solutions and the domains of stability of the various corrosion products.
2. The quantitative electrochemical factors determining the corrosion rate are discussed.
3. A qualitative mechanism for the initiation and propagation of a corrosion pit in aluminum is discussed.

Introduction

A CONTINUING program of research into the fundamentals of pitting corrosion has been under way in Aluminium Laboratories Ltd. for somewhat over two years. As a result of this work and of discussion of the subject with other corrosion workers, certain ideas and opinions have been developed on the nature and mechanism of the pitting corrosion of aluminum. Although these are incomplete at this stage of the investigation, it is considered constructive to present them now to permit study and criticism by others. It is fully realized that as additional facts are revealed some of these opinions will alter and thus it should not be assumed that the present picture of pitting is considered final.

Metallic corrosion is simply reaction of a metal with its environment in which the metal is oxidized into a combined form. In the case of the corrosion of a metal in solution, the reaction products either may be precipitated as solids, or pass into solution in the environment. In the case of aluminum, in neutral and near neutral solution, the reaction products are predominantly insoluble. During the initial stages of corrosion they will be deposited on the surface of the metal. The nature of this initial deposit will affect the morphology of the subsequent attack on the metal and determine the degree of localization of the attack. Thus, a knowledge of the stable reaction products is of importance in studying the distribution of attack on the metal surface.

In addition to this question of distribution of attack, there is the problem of those factors which determine the rate of attack. The pitting corrosion of aluminum has been shown to be electrochemical in nature and thus the rate factors are those which limit the rate of an electrochemical reaction.

Part I—Thermodynamics

The two most common types of corrosion reactions of aluminum and the ones which shall be discussed here are:

a) its reaction with water in the absence of oxygen
b) its reaction with water saturated with oxygen, at a partial pressure of 0.21 atmospheres.

These type reactions have been conveniently summarized by Warner[1] in the following fashion:

In case a), solid metal Al_s must be oxidized by displacing hydrogen, and one is, therefore, concerned with reactions of the type:

$$2Al_s + 6H_2O_l = 2Al(OH)_{3s} + 3H_{2g} \quad (1$$

$$2Al_s + 3H_2O_l = Al_2O_{3s} + 3H_{2g} \quad (2$$

where: s, l, g indicate the states of solid, liquid and gas.

Such reactions are referred to as "hydrogen type." If the process proceeds by an electrochemical mechanism the total reaction may be divided into its anodic and cathodic parts as follows:

$$\text{at anodic areas } Al_s + 3(OH)^- = Al(OH)_{3s} + 3F \quad (3$$

$$\text{at cathodic areas } 3H_2O_l + 3F = 3(OH)^- + \tfrac{3}{2}H_{2g} \quad (4$$

$$\text{or at anodic areas } Al_s = Al^{+++} + 3F \quad (5$$
$$Al^{+++} + 3OH^- = Al(OH)_{3s}$$

$$\text{at cathodic areas } 3H_2O_l = 3(OH)^- + \tfrac{3}{2}H^+ \quad (6$$
$$3H^+ + 3F = \tfrac{3}{2}H_{2g}$$

where F = faradays of charge involved in reaction.

In case b) metal is oxidized by atmospheric oxy-

*A paper presented January 29, 1952 at Ottawa, Ontario to the second annual joint meeting of the Physical Chemistry Division of the Chemical Institute of Canada and Associate Committee on Corrosion Research and Prevention of the National Research Council of Canada. Submitted for publication May 13, 1952.

gen in the solution and one is concerned with reactions of the type:

$$2Al_s + 3H_2O_l + 3/2O_{2g} = 2Al(OH)_{3s} \quad (7$$

$$2Al_s + 3/2\ O_{2g} = Al_2O_{3s} \quad (8$$

Such reactions are referred to as "oxygen type." A division into anodic and cathodic parts yields:

$$\text{at anodic areas } Al_s + 3(OH)^- = Al(OH)_{3s} + 3F \quad (9$$
$$\text{at cathodic areas } \tfrac{1}{2}O_{2g} + H_2O + 2F = 2(OH)^- \quad (10$$

The following table gives the most important anodic and cathodic reactions of aluminum in air saturated water along with the corresponding standard half-cell potentials, from the compilation of Camp.[2]

Anodic Reactions	E°	
$4(OH)^- + Al = H_2AlO_3^- + H_2O + 3F$	+2.35	(11
$3(OH)^- + Al = Al(OH)_3 + 3F$	+2.318	(12
$Al = Al^{+++} + 3F$	+1.67	(13
Cathodic Reactions		
$\tfrac{1}{2}O_2 + H_2O + 2F = 2(OH)^-$	−0.444	(14
$2H^+ + 2F = H_2$	0.000	(15

Now if the anodic members and the cathodic members of this set of reactions are paired two at a time, in the fashion described by Camp[2] and it is assumed that they form the two elements of a galvanic cell, then it is possible to determine, as a function of concentration of the reaction products, which reaction will take place during the corrosion of the metal. That is, it is possible to determine the most anodic of the anodic set of reactions and the most cathodic of the cathodic set of reactions. This can be done by setting up the expression for the electromotive force of the cell and determining the algebraic sign of the galvanic cell potential.

If this is done then the results of these calculations for the neutral air saturated solution are as follows:

1) Reaction (12 is anodic to reaction (11 when $C_{HBAlO_3} > 3.6 \times 10^{-7}$
2) Reaction (12 is anodic to reaction (13 when $C_{Al^{+++}} > 10^{-11.4}$
3) Reaction (13 is anodic to reaction (11 when $C_{HBAlO_3} > C_{Al^{+++}} \times 10^{6.6}$
4) Reaction (14 is anodic to reaction (15 when $p_{H_2} > 10^{-13.3}$

where $C_{Al^{+++}}$ etc. is the concentration of aluminum ions in the solution.

Extension to media of varying pH can be easily made Reaction (4 is unaffected by changes in pH while the effect of pH on the anodic reaction is best expressed by the solubility curve of aluminum hydroxide as a function of pH shown in Figure 1.[6]

The position of these solubility curves varies with the nature of the aluminum hydroxide forming the solid phase. If a fresh precipitate is allowed to age it changes so that its chemical potential per gram mol of alumina diminishes, thus lowering all the solubility lines parallel to themselves. The solubility of

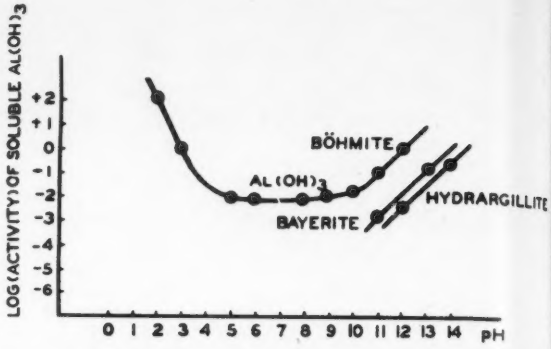

Figure 1—Solubility curve for $AL(OH)_3$ in water.

various types of hydroxide in an alkaline medium is shown very approximately in Figure 1. Thus within the pH range 5 - 9 the solubility remains almost constant at a minimum value. As the pH is increased or decreased outside this range the solubility rises.

In view of these facts the sequence of reactions that take place when aluminum is placed in air saturated water are, assuming the absence of irreversible effects, as follows.

When aluminum is immersed in hydrogen-free air-saturated water the anodic reaction commences with the solution of aluminum as trivalent aluminum and aluminate ions. However, because of the low solubility product of aluminum hydroxide the solution soon becomes saturated and it is precipitated from solution as the ultimate corrosion product.

The cathodic reaction under these conditions will consist initially in the liberation of hydrogen which will probably pass into solution. When the partial pressure of hydrogen exceeds $10^{-13.34}$ atmospheres the oxygen absorption reaction can commence and it proceeds simultaneously with the hydrogen evolution reaction.

The presence of irreversible effects (for example the existence of hydrogen overvoltage) can alter greatly the course of the reactions. Furthermore, no reference has been made to the actual kinetic mechanism of the reaction. This mechanism may consist of simple chemical dissolution or of electrochemical attack: if the latter occurs there is the further question of how the individual reactions occur, i.e. is the alumina produced directly or as a secondary product by precipitation from solution.

These questions properly belong to the following two sections where they will be discussed at least in part.

Part II—Electrochemistry

The system constisting of aluminum immersed in an air saturated solution of an electrolyte constitutes an oxidation reduction system and the corrosion reaction is an oxidation reduction reaction. The oxidation reaction consists of the passage of aluminum from the metallic state to the combined state, while the reduction reaction consists of either the evolution of hydrogen, the absorption of oxygen or the simultaneous occurrence of both these reactions. The passage of metallic ions from the metal lattice into

the combined state may be considered as an anodic current while the simultaneous cathodic reaction or reactions may be considered to correspond to a cathodic current. In the steady state these two currents will be of equal magnitude.

The electrochemical theory of corrosion assumes that the oxidation and reduction reactions occur at discrete areas of the metal surface. In the case of aluminum the electrochemical nature of the corrosion in neutral aqueous solutions has been verified[3] and may be assumed as a convenient working hypotheses in other solutions.

In neutral solutions the most characteristic form of corrosion of aluminum is pitting.[3] In a pitting type of corrosion, the base of the pit where metal is going into solution is per se the anode; the shoulder or walls of the pit, or discrete portions of these, are the cathode of the reaction. Iron, copper and other metals possessing several valence states are covered with an electrically conducting oxide film, experimental evidence indicating that this film is the seat of the cathodic reaction in the case of attack by a neutral medium.

In the case of aluminum, however, the oxide film is a non-conductor and the nature of the site of the cathodic reaction is not clear. The fact that copper deposition on an aluminum specimen immersed in a dilute copper nitrate solution is discrete indicates that the cathodic reaction occurs at discrete points in the oxide film. This follows from the fact that in a copper bearing solution the primary cathodic reaction will be copper deposition and hence copper will only deposit on parts of the surface where a cathodic reaction can occur. These cathodic sites are probably flaws and weak spots in the film resulting from the presence of secondary phases imbedded in the alloy matrix surface. However, this is purely speculative since there is no published information concerning the nature of the sites at which the cathodic reactions occur.

A semi-quantitative discussion of the electrochemical factors which determine the corrosion rates can be carried out without a detailed knowledge of the reaction sites. Let:

E_r = the reversible potential corresponding to the corrosion reaction
E = the cell potential in an operating corrosion cell
I_a = the anodic current
I_c = the cathodic current
A_a = the anode area
A_c = the cathode area
Q_a = the concentration overpotential function of the anode
Q_c = the concentration overpotential function of the cathode
N_a = the activation overpotential function of the anode
N_c = the activation overpotential function of the cathode
R = the ohmic resistance in the corrosion cell

The Q and N functions differ in that the former arises as a result of the electrochemical reaction whereas the latter is inherent in the reaction itself. This can be expressed in the fact that the relation

$$E_r - (N_a + N_c) > O \qquad (16$$

must hold before the corrosion reaction can occur. No concentration overpotential term is needed in (16 since it does not arise until corrosion is under way.

The relation between these quantities before the steady state has been established is as follows:

$$E = E_r - (Q_a + Q_c + N_a + N_c) - IR \qquad (17$$

Under steady state conditions

$$E = O \qquad (18$$

$$I_a = I_c = I \qquad (19$$

and thus

$$E_r = Q_a + Q_c + N_a + IR \qquad (20$$

The Q and N terms are functions of current density of the following form:

$$Q = \frac{RT}{N} \ln 1 - \frac{\frac{I}{A}}{I_o} \qquad (21$$

$$N = \beta + \frac{RT}{\alpha} \ln \frac{I}{A} \qquad (22$$

where I_o is a constant.

The composite anodic and cathodic polarization functions, it is obvious, will be quite complex functions of the current density but it has been found[4] that for aluminum in neutral chloride solutions they may be approximated by a linear function.
Hence

$$Q_a + N_a = \frac{R_a I}{A_a} \qquad (23$$

$$Q_c + N_c = \frac{R_c I}{A_c} \qquad (24$$

where R_a, R_c are constants.

Thus from equation (20

$$E_r = \frac{R_a I}{A_a} + \frac{R_c I}{A_c} + IR \qquad (25$$

$$E_r = I \left[\frac{R_a}{A_a} + \frac{R_c}{A_c} + R \right] \qquad (26$$

$$I = \frac{E_r A_a A_c}{R_a A_c + R_c A_a + R A_c A_a} \qquad (27$$

In the case of the corrosion of aluminum it has been found experimentally[1] that the corrosion process is under cathodic control. Hence

$$R_a \approx O \qquad (28$$

Also in a normal corrosive environment R is also very small and may be ignored. Hence equation (27 becomes

$$I = \frac{E_r A_c}{R_c} \qquad (29$$

Equation (29 gives the dependence of the corrosion rate (expressed as the corrosion current) on the characteristics of the metal and environment, in the case where a steady state has been reached and is being maintained and where the simplifying assumptions employed in its derivation are applicable. It is a straightforward problem to derive an expression equivalent to (29 when equations (21 and (22 are used to compute the polarization functions and mixed control in a high resistivity system is assumed.

As equation (29 shows, the corrosion rate is proportional to the cathodic areas in the metal, to the thermodynamically reversible potential of the corrosion reaction and inversely proportional to the polarization function of the reaction.

The thermodynamic state of both environment and metal will determine E_r, since this is set by the overall chemical reaction constituting the corrosion process. A_c, the total area of the local cathodes and R_c the polarization constant of the local cathodes are also dependent on both metal and environment, although the characteristics of A_c may depend more on the metal than on the environment while the reverse is true of R_c. These points will be elaborated later. It is well to note here that the steady state assumption employed in the derivation of equation (29 may, under many circumstances, be of doubtful validity since accumulation of corrosion products and poisoning of the electrode reactions can quite conceivably occur, thus affecting the polarization functions and making them time dependent.

Equation (29 may be employed at this stage to derive an expression for the rate of penetration of a pit in a metal specimen, keeping in mind, however, all the qualifying assumptions.

If the corrosion current I passes for a time of "t" seconds and if the equivalent weight of the metal is "f" and the numerical value of the Faraday is "F" then a quantity of metal "w" given by

$$w = \frac{It\,f}{F} \qquad (30$$

will be dissolved. Substituting from (29

$$w = \frac{A_c E_r}{R_c} \cdot \frac{tf}{F} \qquad (31$$

If it is further assumed that the pit possesses hemispherical shape of radius "r" then

$$w = \frac{2}{3}\,\pi\, r^3 d \qquad (32$$

where d is the density of the metal. Hence substituting (32 in (31

$$r = \left[\frac{3}{2}\,\pi\,\frac{A_c E_r}{dR_c} \cdot \frac{f}{F}\right]^{1/3} t^{1/3} \qquad (33$$

$$r = Bt^{1/3} \qquad (33a$$

where

$$B = \left[\frac{3}{2\pi}\,\frac{A_c E_r}{dR_c}\,\frac{f}{F}\right]^{1/3} \qquad (34$$

Hence the rate of penetration of a hemispherical pit will be a cube root function of the time after the establishment of steady state conditions. This relation can be altered in a purely ad hoc fashion to take care of deviations in pit shape from a hemisphere by replacing the exponent ⅓ by an arbitrary factor which can be determined empirically.

These equations relating pit depth with time have been employed[4] by Marchand and Hone in correlating their pitting rate studies.

However, in many cases, corrosion products are deposited about the site of the corrosion reaction, which stifle and slow down the corrosion process. Under these conditions it is logical to assume that the total corrosion will follow an equation of the form

$$\frac{dw}{dt} = \beta e^{-\alpha t} \qquad (35$$

Integrating this equation gives

$$w = \frac{\beta}{\alpha} - \frac{1}{\alpha\delta}\, e^{-\alpha t} \qquad (36$$

If there is no appreciable induction period, then $w = O$ when $t = O$ and $\beta/\alpha = \frac{1}{\alpha\delta}$ while the maximum or ultimate loss of weight due to exposure for infinite time ($t = \infty$) is

$$w_\infty = \frac{\beta}{\alpha}$$

Hence equation (36 may be written more simply as

$$w = w_\infty\,(1 - e^{-\alpha t}) \qquad (37$$

Again assuming a hemispherical pit the time dependence of the pit depth is now expressed as

$$r = r_\infty \left\{1 - e^{-\alpha t}\right\}^{1/3} \qquad (38$$

Equations (33 and (38 predict a different dependence of pit depth on time, (33a predicting a pit depth monotonically increasing with time whereas equation (38 predicts a limiting pit depth of r_∞. Which equation governs will depend on the particular conditions obtaining in the corroding system and must be determined experimentally. The assumption of hemispherical pits is rough at best and the change in the functional dependence of r on time with changing pit shape can be best expressed by changing the exponent ⅓ to an empirical factor 1/n.

It is interesting to note that Bengough, Lee and Wormwell[5] in studying the corrosion of zinc, iron and steel in potassium chloride solutions by the gasometric method found two types of corrosion-time curves, an exponential curve in dilute solutions and a linear curve in concentrated solutions. The corrosion in the case of the exponential curve was of a pitting type concentrated upon isolated areas round which rings of interference colors usually were found and over which corrosion product had formed a hard dome-like shell. In the case of specimens yielding a linear corrosion time curve, corrosion gradually spread till the whole of the specimen surface was attacked. The corrosion product in this case appeared as a flocculent non-adherent precipitate throughout the solution.

Part III—Mechanism of Pitting Corrosion of Aluminum

The pitting corrosion of aluminum can now be discussed in terms of the principles developed in the proceeding sections.

Following Pourbaix[6] a metal in a corrosive environment may be considered to exist in one of three domains on its potential pH diagram; corrosion, passivity or passivation. The first of these represents

those conditions of elevated potential where reaction occurs between the metal and its environment, that is to say the metal corrodes. The second of these domains represents those conditions where the potential of the metal is so far depressed that reaction is not thermodynamically possible and the metal is immune to attack. The domain of passivation on the other hand represents those conditions of elevated potential where although reaction is thermodynamically possible, the metal may either wholly or partially escape attack. This partial or complete stifling of the attack is a result of the formation of a protective film, formed by the reaction process itself, which partially or completely isolates the metal from its environment. The possible existence of such a film of insoluble corrosion products can be determined by thermodynamic arguments such as those carried out in Part I. Whether a protective film is formed in practice depends not on thermodynamics but on those kinetic factors which govern the mode of precipitation of the corrosion products from the solution where they are formed as a result of the intermingling of the anodic and cathodic reaction products. In particular the nucleation number and crystal form of the precipitate will determine the protective character of the film. If the nucleation number is low the film will be discontinuous and nonprotective, whereas if it is high precipitation will lead to a continuous protective film, especially if the crystal form of the precipitate lends itself to the formation of an interesting structure.

It is interesting to note that the pitting corrosion of metals occurs under environmental conditions such that the metal is in the domain of passivation. That is, the corrosion reaction results in an insoluble corrosion product, incompletely stifling the reaction, thus localizing the attack and resulting in pitting of the metal.

In the author's opinion the initial air-formed film of oxide which is present on aluminum is not in itself highly protective. This is reasonable because of the complex nature of the metallic surface, which consists of the aluminum alloy matrix grains of differing orientation separated by grain boundaries and with secondary phases imbedded in the matrix surface. In addition, the surface will be in a complex state of strain. In view of this it is quite probable that the surface oxide film formed by direct oxidation of the metal will be in a non-protective state. This, however, need not necessarily be true in the case of an annealed specimen of high purity metal or in the case of a single phase or some polyphase alloys. In the latter case it may happen that the secondary phases form adherent protective films in their own right.

When the metal is immersed in a solution it is possible that in the presence of certain solutes breakdown of the film occurs since some ions, e.g., chloride ions, are known to have a specific peptizing action on alumina (i.e. tend to disperse the alumina colloidally in the solution, thus preventing effective film formation). However that may be, it is to be expected that when aluminum is immersed in a solution, corrosion or dissolution of the metal will occur over most of the surface of the metal, the cathodic reactions of hydrogen evolution and oxygen absorption and the anodic reaction of metal solution not taking place at clearly defined sites. These reactions will result in alkali being formed at the cathodes (resulting in a rise of pH), and in the aluminum salt of the solute anion being formed at the anodes. This aluminum salt will hydrolyze forming the acid corresponding to the anion and alumina in solution. In time the alkaline cathodic products of reaction and the acid anodic products of reaction will intermingle through the processes of diffusion and convection. How they would intermingle would depend on many indeterminate factors. As they intermingle the pH of the anodic solution rises and the solubility product of the alumina in solution will be exceeded resulting in precipitation of alumina from the solution. The condition of the precipitated alumina will depend on the environment. In two component systems of the alkali halides, the precipitation will take place in the body of the solution as a flocculent highly dispersed non-protective precipitate since chloride ion is a peptizing agent for alumina. Under these conditions stifling of the reaction will not occur and general corrosion will develop.

Under other environmental conditions the alumina will be precipitated as an adherent protective film in contact with the metal surface, effectively stifling the corrosion process. This appears to happen in pure nitrate solutions, time potential curves indicating complete and rapid stifling of the corrosion reaction, whereas such measurements show continued corrosion of aluminum when it is immersed in pure chloride solutions.

Intermediate between these two cases it may happen that partial but not complete stifling of the reaction occurs—resulting in localization of the attack. The exact conditions under which this occurs are not known. However, what probably happens in practice is that most of the surface is covered by a tightly adhering film while the sites of potential pits are covered with a dome of non-protective alumina precipitate. Under these conditions, the cathodic and anodic reactions continue; the pH at the anodic area decreases, resulting in solution of the film surrounding the pit site. The area of attack thus expands, but as it does so, it undermines the dome of precipitate so that the acid and alkaline products of reaction can again intermingle, resulting in precipitation of alumina. Under the environmental conditions some of this will be precipitated in a non-protective form while the remainder will be precipitated in a protective form limiting the lateral expansion of the attack. Corrosion will then proceed in a vertical direction with the resultant formation of a pit. As the pit deepens, precipitation of the protecting film will occur first in the mouth of the pit and then down the walls of the pit, so that the cathodic reaction follows the anodic base of the pit.

Thus, areas temporarily or permanently free from corrosion are covered with a precipitated protective film formed by the corrosion process itself. The particular form of corrosion product which gradually

builds up in mounds can act as an oxygen screen greatly cutting down the corrosion rate.

The geometry of the attack on the metal will depend on the physico-chemical state of the metal; the degree of cold work introduced into the metal, the relative orientation and size of the metal crystals, the presence of local strains and other indeterminate factors. Thus, various areas of the metal will differ in chemical potential and varying intensities of attack are to be expected over the anodic areas. Superimposed on this will be variations in the anodic polarization factor thus introducing additional variations in intensity of attack.

Corrosion pits in aluminum frequently appear to be surrounded by an annular ring showing interference colors which indicate a thickness of from 300A° to 1000A° (compared to about 50A° for the normal oxide film); this will consist of the precipitated protective film formed by the corrosion process itself.

Once the pit has been initiated it will propagate. The rate of propagation will be governed by the electrochemical factors discussed in the preceding section especially by anodic and cathodic polarization factors and the effect of precipitated alumina.

Termination of the pit propagation can occur through precipitation of corrosion product over the anodic areas of the pit laying down a protective film and stifling attack. If this process is incomplete, i.e., if the film is not completely protective this can concentrate the corrosion still more and lead to very rapid perforation.

The pertinent points of the discussion of this section can be conveniently summarized as follows:

1) The pitting corrosion of aluminum occurs under environmental conditions where an insoluble corrosion product is formed which incompletely protects the surface and thus leads to localization of attack.
2) The mechanism of pitting involves three distinct stages:

a) *Initiation*

Closely related to the initiation of pitting is the question of the distribution of corrosion, i.e., the probability of pitting. This will be determined by factors which are both environmental and metallurgical. Environmental conditions will affect the distribution of pitting by affecting the nature of the corrosion product and its distribution over the surface of the metal. The distribution of attack will also be affected by the continuity and uniformity of the initial oxide film on the metal and this will be a function of the physico-chemical state of the metal surface.

b) *Propagation*

Here again both environmental and metallurgical conditions will affect the propagation of a pit by affecting the anodic and cathodic polarization function and the type and distribution of the precipitated corrosion product.

c) *Termination*

Convection currents bringing about intermingling of the anodic and cathodic products of reactions can produce precipitation of a protective film over the active anodes thus stifling the corrosion.

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Radiometric Study of The Adsorption Characteristics of Stearic Acid*

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Abstract

A radiometric test method to measure the amount of adsorption of polar organic rust inhibitors was developed and is described. The choice of stearic acid for this initial work was made because of its known adsorption characteristics. The effect of several variables on the amount of adsorption was also studied. These variables included time of immersion, agitation vs. quiescent immersion, drainage time and temperature, and concentration. It was found that the amount of stearic acid adsorbed increased with time of immersion, when coupons were agitated as compared to quiescent immersion and with increased stearic acid content in the solution. The amount of stearic acid adsorbed was found to be independent of the drainage time and temperature. The results of this work indicate that the method may be extended to the study of the adsorption characteristics of petroleum sulfonates and other corrosion inhibitors.

Introduction

THE USE OF polar organic compounds as corrosion inhibitors in petroleum derivative rust preventives has been common practice for a number of years. However, according to Campbell,[1] the mechanism whereby these additives act is not fully understood. He further states that there are two possible explanations of their action:

1) Additive molecules are more strongly adsorbed on the steel surface than are water molecules, forming a close packed oriented layer through which water has trouble diffusing and which it cannot displace, and

2) The free molecules outside the adsorbed film bind excess water, forming a creamy emulsion which has marked water repellent qualities and offers high resistance to diffusion of water and oxygen.

Since the amount of additive adsorbed on the steel surface is very minute, generally of the order of a few molecular layers thick, the measurement of the amount of adsorption has been impossible by usual techniques. Therefore, the use of radioactive tracers for evaluating the amount of adsorption has been proposed. Some work has been reported by Hackerman[2] on the adsorption of stearic acid on steel using radioactive tracers.

The purpose of the work to be covered in this report was to develop a method for measuring the amount of adsorbed inhibitor on steel surfaces. Stearic acid was selected as the polar organic compound for the investigation because it was known to possess definite adsorption characteristics. This work was planned as a preliminary investigation to be followed by similar investigations of presently used inhibitors such as the petroleum sulfonates.

The work also was planned to answer several questions pertaining to the preparation of corrosion test specimens and the processing of materiel in rust preventive oils. The questions covered such subjects as:

1. Time of immersion
2. Agitation versus quiescent immersion
3. Time and temperature of draining
4. Concentration of the inhibitor.

Materials Employed

The radioactive stearic acid used for this investigation was tagged with carbon 14 in the carboxyl group and was procured from the U. S. Testing Company, Inc., of Hoboken, N. J., by authorization of the Atomic Energy Commission Isotopes Division.

All of the tests with the exception of the concentration tests were conducted using a solution containing 10 millimoles of stearic acid per liter. Approximately 5 percent of the total stearic acid was of the radioactive variety while the remainder was normal C. P. stearic acid. The radioactive material as furnished had a specific activity of 1 millicurie per millimole and the solution used was calculated to have an activity level of 0.5 microcurie per milliliter.

The solvent employed was a 100 percent conventionally treated Gulf Coast neutral oil with a viscosity of 55-60 centistokes at 210 degrees F which was obtained from the Sinclair Refining Company. An oil was selected as the solvent for these tests to approach more nearly the actual conditions of inhibited rust preventive oils.

All test coupons used for these tests were made of SAE 1020 steel and were 0.975-inch in diameter and 1/16-inch thick. This size was selected so the coupons would fit the ring supports used with the Tracerlab Automatic Sample Changer which was used in conjunction with a Tracerlab Autoscale for all of the tests except the effect of concentration tests. A 0.073-inch hole was drilled 1/16-inch from the coupon edge for ease of handling with wire hooks.

Removal of Oil Film

The basic plan for this work consisted of immersing a clean sandblasted steel coupon in the stearic acid-oil solution under variable conditions, allowing time for drainage, removing the excess oil film and unadsorbed stearic acid and then counting to determine the relative amounts of stearic acid adsorbed.

The primary problem was to develop a uniform coating removal procedure which would insure that

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all oil and the stearic acid not truly adsorbed had been removed. The use of a vapor degreaser appeared to offer the best possibility as there was less chance of solvent contamination and subsequent redeposition of the stearic acid. After selection of the vapor degreaser method, it was necessary to conduct tests to determine the number and duration of degreasing cycles required to insure that the leveling off point in removal had been reached. The term "leveling off point" for these tests was defined as the point beyond which further degreasing did not reduce the counting rate by more than 0.1 count per second.

Several tests were conducted to determine the optimum procedure for degreasing. For each test 30 coupons were sandblasted, cleaned, dipped individually in the 10 millimole/liter stearic acid-oil solution for 5 minutes, and drained at room temperature for 18 hours. The coupons were then divided into 6 groups of 5 coupons each, which were then given degreasing cycles of 5, 15, 30, 60, 120 and 180 minutes, respectively. After each degreasing cycle, the coupons were cooled and counted, using a Geiger-Muller mica window tube. All counting runs were made for a predetermined count of 640 counts. The results of a typical test are presented in Table I, where the average counting rates after each degreasing cycle are given for each group of 5 coupons.

The following conclusions may be drawn from the data presented in Table I:

1. The leveling off point is approximately the same, regardless of the length of the degreasing period.
2. The decrease in counting rate for a longer degreasing period is only slightly greater than for a shorter period.
3. The leveling off point may be reached in the shortest overall time by employing a treatment consisting of eight 5-minute cycles.
4. Based on the above conclusions, the procedure to be followed for all future tests will consist of eight 5-minute degreasing cycles with 10-minute cooling periods interspersed.

Tests conducted using a rinsing procedure in benzene, naphtha or a 50/50 mixture of benzene and naphtha revealed that these methods were not as effective as the vapor degreasing procedure when 2-minute rinsing treatments were employed. Based on the results of these tests and the fact that there is a problem of solvent contamination and redeposition, as mentioned previously, no further consideration was given to these methods of coating removal.

Type of Panel Surface

During the preliminary experiments which employed sandblasted coupons, it was found that the reproducibility of the results for identically treated coupons was not as good as expected. Therefore, it was thought advisable to investigate the use of polished steel coupons, although not considered preferable since rust preventive oil tests employ sandblasted panels.

For these comparative tests, due to the much lower adsorption values on polished surfaces, it was found necessary to use a windowless flow gas counter rather than the mica window tube to improve the counting efficiency and produce higher counting rates.

The procedure used was as follows:

1. Prepare 10 sandblasted and 10 polished coupons and clean.
2. Agitate each coupon individually for 5 minutes in the stearic acid-oil solution used for the previous tests.
3. Drain 18 hours and then degrease in accordance with the established procedure.
4. Cool and count using the windowless flow counter.

The results of one test are presented in Table II, where the times required to totalize 3200 counts are tabulated for each of the 10 coupons in each group. The coefficient of variation which is the ratio of the standard deviation to the average expressed as a percentage is also presented as a measure of dispersion for each group. It will be noted that the coefficient of variation for the sandblasted coupons is 8.1 percent as against 13.9 percent for the polished coupons. This indicates that there is less dispersion or, conversely, better reproducibility when sandblasted coupons are used. Therefore, all further tests were conducted using sandblasted coupons.

Effect of Immersion Time and Agitation

This portion of the investigation is the first portion devoted to obtaining the solution to various practical problems regarding the mechanics of preparing test panels and processing materiel in rust preventive oils. The effects of time of immersion and agitation on the amount of inhibitor adsorbed have been long considered of importance, but no techniques for their measurement had been developed previously.

For these tests 10 groups of 3 or 5 sandblasted coupons each were employed. The coupons were treated as detailed previously, except for varying the dipping procedure. One group was merely dipped while a companion group was agitated at a speed of 60 cycles a minute for each of the following periods: 1, 3, 5, 10 and 20 minutes. The number of coupons

TABLE I

Determination of Optimum Degreasing Procedure

Cycle No.	TIME OF DEGREASING CYCLE, MINUTES					
	5	15	30	60	120	180
	(Net Counts per Second)					
1	4.17	3.92	3.91	3.17	2.67	3.02
2	3.49	3.18	3.15	2.84	2.26	2.20
3	3.21	2.85	2.84	2.66	1.64	1.78
4	3.04	2.72	2.24	1.82	1.54	1.68
5	2.55	2.33	1.85	1.75		
6	2.02	1.86	1.78			
7	1.86	1.91				
8	1.81					

TABLE II

Sandblasted Versus Polished Surfaces

Time in seconds to totalize 3200 counts

	Sandblasted Coupons	Polished Coupons
	160	245
	157	224
	161	321
	158	252
	174	316
	193	242
	173	325
	163	234
	165	298
	197	310
Average...	170.1 ± 13.8	276.7 ± 38.6
Net Count.	18.00 c/s	10.75 c/s
Coefficient of variation	$\frac{13.8 \times 100}{170.1} = 8.1\%$	$\frac{38.6 \times 100}{276.7} = 13.9\%$

Background Count = 0.81 c./s.

used per group was increased in the later tests to improve the accuracy of the average value. This was found to be particularly advantageous when it was found necessary to discard one value as a suspected determination based on Chauvenet's Criterion.

The order of dipping was also changed during the later tests in an endeavor to compensate for depletion of activity and stearic acid in the solution. It was believed that the depletion effect might be a contributing factor to the erratic results obtained in the original tests. The order of dipping first employed was to dip all the coupons of one group and then proceed to the next group in the following order; 1 minute dip, 1 minute agitate, 3 minute dip, etc. The second manner of dipping used involved treating one coupon from each group at a time in the order mentioned and then repeating the cycle four times to complete the preparation of the 10 groups of 5 coupons each. It was found by comparing the individual counting rates of coupons within the same group that no definite trends of depletion existed.

The results of the several tests conducted followed the same general pattern, although there were instances where individual group averages did not fall into the established pattern. These discrepancies may be accounted for by one or more of the following reasons:

1. Randomness of atomic disintegration
2. Non-uniformity of coupon surface finish
3. Variations in degreasing effectiveness
4. Inconsistencies in operation of the counting equipment.

Therefore, in an effort to minimize the errors resulting from the above causes, the results of seven separate tests have been grouped together and presented as grand averages in Table III. The averages presented for each test condition represent the counting rates of 31 individual test coupons. The following conclusions may be drawn from the data presented in Table III:

1. The degree of adsorption of stearic acid increases with the time of immersion. This increase is greater in the case of coupons agitated than when coupons are merely dipped in the test solution. This latter fact may be attributed to the lowered concentration of stearic acid at the liquid-metal interface in the case of the dipping tests, while the concentration at the interface is replenished by agitation of the coupons in the solution.
2. The percent increase in adsorption resulting from agitation (Column 4 of Table III) remains quite constant for the lower immersion times, but for the 10 and 20-minute immersion times the value increases greatly. This may be explained by the same theory of stearic acid depletion at the liquid-metal interface mentioned above.
3. In the case of the dipped coupon results, it will be noted that the counting rates increased with time up to 5 minutes and then dropped off and increase again for the 20 minute test. This may be explained by the theory that the concentration at the interface becomes depleted with increased time of immersion resulting in a lower rate of adsorption.

TABLE III

Effects of Immersion Time and Agitation
Grand Averages of Seven Tests

TIME OF IMMERSION (Minutes)	Dipped (Net Counts/Second)	Agitated (Net Counts/Second)	Percent Increase
1	11.76	14.81	25.9
3	13.93	17.73	27.3
5	15.20	18.80	23.7
10	14.35	21.18	47.6
20	17.12	26.65	55.7

Effect of Drainage Time and Temperature

Present government specification for rust preventive oils require various drainage times and temperatures, the basis for which has long been obscure. Therefore, this portion of the investigation was devoted to an endeavor to determine what effect, if any, time or temperature of drainage had upon the amount of adsorption of an inhibitor.

Several tests were conducted using coupons processed as for the previous tests and standardizing upon a five minute agitation of the coupons in the stearic acid-oil solution. The results of three tests employing different times of drainage are presented in Table IV. Each value represents the average of the counting rates of five coupons. It will be noted that no definite trend may be detected, indicating that the time of drainage has little or no effect upon the amount of stearic acid adsorbed. The variations noted may be attributed to any one or combination of sources of error previously mentioned.

Two tests were also conducted to determine the effect of drainage temperature, using temperatures of 70 degrees and 130 degrees F, both of which are mentioned in current specifications. The average counting rates in net counts/second representing ten coupons each are presented below:

	Test C-3	Test C-3a
70° F	13.47	18.43
130° F	15.41	18.94

It will be noted that the effect of drainage temperature is negligible as small differences such as are shown may be due to errors previously mentioned.

Effect of Stearic Acid Concentration

This final portion of the investigation, while of a more academic nature, is also of practical worth when one considers the problem of rust preventive oil formulation where the effect of inhibitor concentration on the degree of adsorption must be known.

For this phase of the investigation, solutions of stearic acid in benzene were used to assure complete solution of the solute. The solutions used had concentrations of 5, 10, 15, 20, 25 and 30 millimoles of stearic acid per liter. All solutions contained the same amount of radioactive stearic acid (approximately 14 mg) which represented about 5 percent of the total amount contained in the 10 millimole/liter solution.

The specific activities (counts/minute/gram) of the six solutions were determined by pipetting a known amount of the solution into a previously tared stainless steel cup and then evaporating the solvent

TABLE IV

Effect of Drainage Time

TIME OF DRAIN (Hours)	Test B-7 (Net Counts/Second)	Test B-7a (Net Counts/Second)	Test B-7b (Net Counts/Second)
2	18.05	14.24	13.80
4	20.22	13.74	11.11
6	20.51	15.17	10.20
18	20.81	16.91	12.70
24	19.40	13.61	10.75
48	19.70	15.26	10.75
72	21.46	13.95	11.81
96	22.18	14.93	10.28

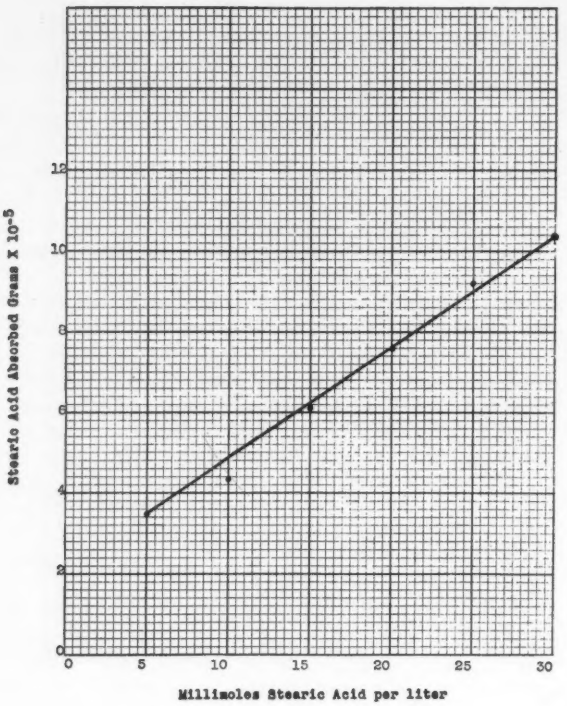

Figure 1

TABLE V
Specific Activity Results

SOLUTION (Millimoles)	Test No.	Weight of Residue (Grams)	Net Counts/ Min.	Specific Activity ($X10^6$)
5	D-4	0.0018	37029	20.57
	D-4b	0.0018	38708	21.50
10	D-4	0.0018	18034	10.02
	D-4b	0.0020	19284	9.64
15	D-4	0.0018	11514	6.40
	D-4b	0.0019	10929	5.75
20	D-4	0.0018	7548	4.19
	D-4b	0.0020	8770	4.38
25	D-4	0.0018	5989	3.33
	D-4b	0.0023	7361	3.20
30	D-4	0.0018	5432	3.02
	D-4b	0.0024	6123	2.55

TABLE VI
Effect of Solution Concentration

SOLUTION (Millimoles)	Net Counts/Min.		Stearic Acid Adsorbed (Gms. $X10^{-5}$)		Average of Two Tests
	Test D-4	Test D-4b	Test D-4	Test D-4b	
5	807	631	3.92	2.93	3.43
10	475	380	4.74	3.94	4.34
15	411	335	6.42	5.82	6.12
20	382	267	9.11	6.09	7.60
25	346	256	10.39	8.01	9.20
30	327	248	10.82	9.72	10.27

under an infra red lamp until a constant weight was obtained. The samples were then counted. The amount of solution used was calculated to give the same weight of residue to obviate the necessity for applying self absorption corrections to the counting rates. The volumes used are listed below:

5 millimole solution — 1.2 ml.
10 millimole solution — 0.6 ml.
15 millimole solution — 0.4 ml.
20 millimole solution — 0.3 ml.
25 millimole solution — 0.24 ml.
30 millimole solution — 0.2 ml.

The results of the specific activity tests are presented in Table V. Two identical tests were conducted and are designated tests D-4 and D-4b. It will be noted that the agreement between the two tests is quite good considering that the weight of residue in Test D-4b was not constant and may have had some effect on the counting rates due to variations in the amount of self-absorption for which no corrections were made.

After determining the specific activities of the solutions, it was possible to correlate the counting rates of immersed coupons with the specific activities to determine the weight of stearic acid adsorbed. This was done by preparing five sandblasted coupons for each solution. After cleaning, each coupon was agitated for 5 minutes in the test solution, air dried and then desiccated until counted.

All counting was done using a thin mica window Geiger tube (TGC-2) from Tracerlab, Inc., mounted in a 1½-inch lead shield with the samples placed about 10 mm from the tube window. The scaler employed was a Nuclear Chemical & Instrument Company Ultramatic Scaler, Model 172. Cups for the specific activity determination were counted for a total of 12,800 counts and coupons for a total of 1600 counts.

The results of the two adsorption tests are shown in Table VI, along with the average amount of stearic acid adsorbed. The average results are plotted in Figure 1 where it will be noted that the amount of stearic acid adsorbed per coupon in grams x 10^{-5} varies directly as the concentration. There is a possibility that this curve may level off at higher concentration, but based on the work done, this has not been definitely proved.

Summary

The work covered in this report has definitely established the feasibility of using radiometric techniques for the determination of the degree of adsorption of polar organic compounds on steel surfaces. The method, as developed, is believed to be adequate for extension to the study of organic rust preventive inhibitors such as the petroleum sulfonates. This will then make it possible to evaluate the various sulfonates as to their rate of adsorption on steel.

The answers to the several practical problems studied will provide information for the preparation of future specifications for rust preventive oils. This information will, however, only serve as a guide when the adsorption of the inhibitor on the steel is considered to be of major importance. If the inhibitor is believed to protect by virtue of the emulsion built up, this information will, of course, not apply.

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The opinions or assertions contained herein are not to be construed as being official or reflecting the views of the Department of the Army.

The Present Status of Bacterial Corrosion Investigations in the United States *

By CARL G. DEUBER*

Abstract

Since the first studies with bacterial corrosion of underground pipe lines in 1939 in the United States chief interest has been centered in this subject in the Eastern states. Indications are that the causative sulfate-reducing bacteria and the characteristic anaerobic soils associated with their corrosive action are actually widely distributed. Various reasons are suggested for the limited interest in bacterial corrosion. Salient features useful for the detection of bacterial corrosion are described and preventive measures are discussed.

AT THE DECEMBER, 1951 Symposium on the Corrosion of Buried Metals in London, the discussion brought forth the observation that a great majority of pipeline failures in Britain have been associated with unmistakable symptoms of microbiological influence. Since interest in bacterial or anaerobic corrosion began about the same time, in the late 1930s, in Great Britain and in the United States it is timely to enquire into the developments that have occurred in this country. Particular attention will be given to the applications that have been made of the concept in corrosion engineering.

The initial theory of specific bacteria participating in a type of electro-chemical corrosion was proposed by Wolzogen Kühr and van der Vlugt[1] in 1934 in Holland. Explanations were being sought for the severe graphitization of cast iron pipes in the flat, low-lying, poorly drained and poorly aerated (anaerobic) soils. These soils were generally black due to the production of sulfide by anaerobic sulfate-reducing bacteria. The presence of soil acids and the sulfide content of these soils were inadequate to account for the severe corrosive action found on buried ferrous structures. The mechanism proposed for the action of the *Sporovibrio desulfuricans* bacteria in corrosion was that in one phase of their metabolic processes, polarizing hydrogen was being removed from cathodic areas.

In 1937 von Wolzogen Kühr[2] presented his views on the corrosion of iron in the absence of free oxygen at an International Corrosion Conference in Washington, D. C. Shortly after this Hadley[3,4,5,6] began reporting the results of corrosion surveys along gas pipe lines in Ohio and Pennsylvania. Hadley[7] also studied the mechanism of anaerobic corrosion with culture solutions in specially designed corrosion cells. In the Philadelphia area Ganser[8] concluded that much corrosion previously attributed to stray-current electrolysis was actually due to the action of sulfate-reducing bacteria.

During World War II several significant investigative programs were in progress. For the Office of Scientific Research and Development, Starkey and Schenone[9] were working on the microbiological and zoological aspects of paint destruction and metal corrosion along the Eastern Seaboard. Many data were collected on the abundance of sulfate-reducing bacteria in the corrosion products of steel test panels in various marine sites and on the hulls of ships. Fouling organisms were considered to be one of the principal agents for the distribution of sulfate-reducing bacteria in sea water. Between 1941 and 1945 the American Gas Association[10] supported a comprehensive project on anaerobic corrosion of iron in soil. One of the major objectives was the development of an instrument for field determinations of soil redox potentials as indicators of soil corrosiveness. More will be said of this advance later.

The concept of anaerobic corrosion was applied to water mains in an Ohio steel mill by Thomas[11] as well as to the rapid failure of a water pipe line in Texas. The inside of these pipes carried heavy deposits of ferrous sulfide. Clark and Nungester[12] were concerned with the corrosion of the water-cooling pipes of a steel mill and from evidence of free sulfur and sulfides in the corrosion products, the odor of hydrogen sulfide in the exhaust cooling water and the isolation and identification of sulfate-reducing bacteria concluded that these bacteria were the primary cause of the severe corrosion encountered.

Wilson[13] suggested that soil tests for sulfate-reducing bacteria could be made with a pH indicator since these microorganisms thrive chiefly in a neutral reaction. At the National Bureau of Standards, Romanoff[14] studied the effects of air-drying soils on the hydrogen ion concentration. The data showed that large changes occurred in the pH of poorly drained soils as they passed from the moist field condition to the air-dried state. For reliable pH measurements of soils it is essential that they be made under the field condition.

On an Oklahoma gas transmission line in anaerobic sites Huddleston[15] found severe corrosion. The leak frequency was at a maximum during the eleventh year and many pits were two-thirds of the way through the pipe wall. With the installation of cathodic protection no further difficulty with pit-hole leaks was experienced. In a laboratory investigation, Hunter, McConomy and Weston[16] found that the sulfate-reducing bacteria were inhibited when the reaction of the medium was above pH 9.0.

In New York on the Consolidated Edison Company system studies of the leak frequencies on bare steel mains by Gorman and Kulman revealed facts pointing to bacterial corrosion as a major cause of the trouble. Statistical analyses of the data showed that

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the most severe corrosion was occurring in dense, poorly drained clay soils containing organic residues. The hydrochloric acid test of the corrosion products gave evidence of ferrous sulfide in 81 percent of the cases of severe corrosion. This led to an investigation of the microbiological factors involved. Progress results of this program were given in papers by Kulman,[17] Deuber and Kulman[18] and more complete data by Kulman.[19] Bacteriological work indicated the presence of sulfate-reducing bacteria, other anaerobes and sulfur-oxidizing bacteria in the soils of test sites where severe corrosion was occurring. In subsequent work the seasonal fluctuations in bacterial populations were followed at one test site. These data showed that the sulfate-reducing bacteria were most numerous in late spring—the period when corrosion was most active. This investigation has confirmed the earlier indications that bacterial corrosion is a very significant factor in the New York area.

Reports of the occurrence of bacterial corrosion on metal structures other than underground pipe lines and a few instances of water mains and water-cooling pipes have been limited in the United States. A case of anaerobic corrosion of tanks containing cutting oil emulsions was described by Liberthson.[20] Doig and Wachter[21] gave an account of casing corrosion in the Ventura field due to bacterial action and means for overcoming it. Oxley[22] mentioned that caissons in the vicinity of flow stations at Lake Maracaibo require adequate interior protection since corrosion at this location is suspected of being due to anaerobic bacteria. No record of trouble in the water seal of gas holders has been noted. This has been found to be serious in English experience.[23, 24]

Detection of Bacterial Corrosion

When excavations are made to permit pipe inspection the occurrence of bacterial corrosion is indicated by the nature of the corrosion and the characteristic corrosion products. This may be supplemented with the isolation and identification of the sulfate-reducing bacteria. When direct pipe inspection is not possible or new locations are to be estimated as to corrosiveness due to bacterial action, it is necessary to rely largely on site and soil characteristics known to be correlated. The greatest practical interest centers in the latter methods. Before discussing site characteristics the nature of the corrosion products and the determination of the sulfate-reducing bacteria will be briefly reviewed.

The Corrosion Products. The characteristic effect of bacterial corrosion on steel is pitting. When severely corrosive conditions prevail the pits are formed close together and fuse to produce large corroded areas or slabs. At times a black hard crust is formed but beneath this there is a soft, graphite-like paste, generally black but it may contain a thin white layer of ferrous hydrate. With the addition of weak hydrochloric acid the corrosion products give a positive test for sulfide. The corrosion products are loosely attached and when wiped off a bright metal surface is exposed.

The corrosive attack on cast iron results in the formation of porous, soft corrosion products rich in carbon or graphite. Ferrous sulfide is always present. The corrosion products are not adherent but are porous and may contain an admixture of soil particles. When the corrosion products are removed the metal is left without a protective surface film and is bright and silvery. On exposure to air corrosion is rapid.

Identification of Sulfate-reducing Bacteria. A number of strains of the *Sporovibrio desulfuricans* bacteria occur in soils in many parts of the world and in fresh and salt waters. They are found at great depths as in oil wells, Doig and Wachter[21] and in sulfur-bearing salt domes, Miller.[25] In salt water they are frequently associated with fouling organisms and in fresh water mains they may occur in large numbers in the interior layers of iron bacteria tubercles, Butlin, Adams and Thomas.[26]

The bacteria are small curved rods or vibrios. They are motile and at times occur in spiral chains. Culture techniques have been described by Starkey[27] and tentative methods for identifying and estimating these bacteria were published by the American Society for Testing Materials.[28] Miller[29, 30, 31] investigated special features of their physiology. A special soil sampling device was developed by Kulman[17] for securing soil samples unchanged in moisture, air and other characteristics from subsoils at pipe depth.

While it is desirable to determine the presence of the sulfate-reducing bacteria from sites in which anaerobic corrosion is suspected, their absence or presence in low numbers does not necessarily mean that this form of corrosion will not take place. These bacteria tend to migrate to the site of corrosion and multiply there. Starkey and Schenone[9] found that sea water at test sites frequently contained small numbers of bacteria but the corrosion products contained large numbers. The same is found in the soil. The corrosion products in pits usually contain numerous bacteria.

Characteristics of Anaerobic Sites. The sites most frequently affected are flat, low-lying lands, swamps or areas adjacent to water which maintains the water table at a high level. Dense soils such as clays and clay loams which are poorly drained and poorly aerated are most commonly involved. Peat and mixtures of peat and sand are frequently anaerobic. Decaying organic matter favors the rapid multiplication of the sulfate-reducing bacteria.

A neutral or near neutral soil reaction is associated with severely corrosive anaerobic sites. Eastern soils more acid than pH 5.5 were not found to be severely corrosive due to bacterial action in the survey work of Starkey and Wight.[10]

Poorly aerated neutral soils with low oxygen tensions become reduced to varying degrees. In these soil environments anaerobic sulfate-reducing bacteria thrive. The degree of reductiveness of soils is measured by determining the oxidation-reduction potential. This is also termed the redox potential or Σ. The redox potential is a potential measured at an inert metal surface such as a platinum electrode with a hydrogen or calomel electrode for reference. The redox potentials express the intensity of oxidation or the intensity of reduction but not the amounts of oxidized or reduced ions present. These potential

are influenced by the hydrogen ion concentration so that the pH is determined to evaluate the significance of the soil redox potentials.

Significant advances were made by Starkey and Wight[10] in developing field methods for determining the pH and E_h of soils in place. A soil or redox probe was developed for placing the electrodes of a standard pH meter in the soil to a depth of 3 to 4 feet. This instrument was successfully used in wet soils but was not suited for use in moist or dry soils. Survey work with the soil probe in the East gave good correlations between the degree of bacterial corrosion as shown by the E_h values of the reductiveness of the soil and from pipe inspections. The following scale was formulated for estimating soil corrosiveness from soil redox potentials:

Range of Soil E_h	Corrosiveness
Below 100 mv	Severe
100 mv to 200 mv	Moderate
200 mv to 400 mv	Slight
Above 400 mv	Non-corrosive

As the significance of poor aeration in soils as related to corrosiveness becomes more widely recognized, soil redox data will be more frequently determined. Logan[32] prominently lists poor aeration as a common factor in the more corrosive soils. Dennison and Romanoff[33, 34] find that soil exposure tests of the National Bureau of Standards continue to show that the factor which induces corrosion most generally is deficient aeration.

Prevention of Bacterial Corrosion

Relatively few investigations have been concerned with specific measures to be taken to prevent corrosion in anaerobic neutral soils in which sulfate-reducing bacteria are active. The inhibitory action of certain acriflavine and proflavine dyestuffs was studied by Rogers.[35] Suggested applications included the treatment of circulating water in closed systems involving heat exchangers containing condenser tubes, or stagnant water in cable storage tanks, etc. One American manufacturer[36] supplied an anaerobic microbiological corrosion inhibitor with its shields for welds and insulating couplings.

With water supplies in a steel plant, Thomas[11] found that chlorination to yield a residual amount of chlorine in the water of 0.5 ppm destroyed most of the less resistant microorganisms and many of the sulfate-reducing bacteria. In addition to chemical treatment of the water, coating of the inner pipe walls with a coal-tar base enamel retarded the growth of microorganisms and protected against corrosion cells that arise from bacterial deposits. In an investigation of the hydrogen sulfide production process in sewage Eliassen, Heller and Kisch[37] found that the addition of chlorinated hydrocarbons such as orthodichlorobenzene, when properly emulsified, inhibited the initial production of hydrogen sulfide. This treatment kept the sewage in a relatively fresh state for a long enough time to permit its passage in this condition through the sewer system. Mixed populations of microorganisms normally lowered the oxidation-reduction potential of the sewage to a range of - 200 to - 300 millivolts. This range is favorable to the activities of *Sporovibrio desulfuricans.*

When soil surveys indicate localized areas of anaerobic soils with associated criteria of potential bacterial corrosive influence, it may be possible to install pipe lines to avoid such areas. Under some conditions the quality of the backfill may be improved by screening the soil, removing clods of clay or masses of decaying vegetable matter. Clean sand or gravel may be brought in to surround the pipe and create an aerobic environment. Studies by Hunter et al[15] indicated the possibility of inactivating sulfate-reducing bacteria by modifying the soil reaction. An alkaline range greater than pH 9.0 to 9.5 is required to obtain a suspended state of activity of these bacteria.

The major corrective measures being followed by the corrosion engineers of one eastern public utility company[38] to reduce corrosion by the bacterial influence are 1) the installation of insulating joints; 2) the application of protective coatings; and 3) coatings supplemented with cathodic protection.

Insulating joints prevent the flow of "long-line" galvanic currents caused by major changes in soil texture, aeration and drainage. They also serve in underwater crossings to prevent the discharge of corroding current from the submerged pipe.

Acceleration of the corrosion rate by sulfate-reducing bacteria in soil or water occurs when these microorganisms are in contact with bare areas of the ferrous metal and in pits. Insulating the pipe surface from the environment and the bacteria by impervious coatings is therefore one of the most practical preventive measures. Recently, some progress results were reported in London[39, 40] of pipe coating tests in water-logged clay soils in which bacterial corrosion was known to be widespread and serious. In one test, sections of a 4-inch main were variously coated and one section was buried in 9 inches of gravel with no coating. After three years a ⅜-inch bitumen coating and one of three inches of Portland cement concrete and the gravel afforded good protection. A standard 0.005-inch coating by hot-dipping in coal tar gave inadequate protection. With the latter the iron was pitted and attacked in other ways. Bacteriological examination showed the presence of numerous sulfate-reducing bacteria.

The second investigation, by Hudson and Acock[40] presented the results of a 5-year soil burial test of cast iron and steel tubes in five soils. The seamless steel tubes suffered the least pitting. It was found that the 5-year exposure was too short for testing the usefulness of the protective coatings. Excellent results were observed with ¼-inch thick bitumen on steel tubes and with vitreous enamel on cast iron.

In the more aggressively corrosive soils and for the more important sections of a distribution system where the additional costs are warranted, coatings may be supplemented with cathodic protection. Hadley[7] pointed out that the current densities required to obtain complete protection may be high. Minimum protective current densities of 15×10^{-6} to 50×10^{-6} amperes per sq. cm. were measured in an active microbiological anaerobic environment. Pearson[41] gave the orders of magnitude of protective currents

for steel in anaerobic neutral soil with active sulfate-reducing bacteria as between 4 and 5 x 10^{-5} amperes per sq. cm. Some of the limitations of cathodic protection are also discussed by Pearson.

The Mechanism of Bacterial Corrosion

The principal theory of the manner in which the *S. desulfuricans* bacteria accelerate corrosion is that put forth by the Dutch investigators.[1] In one stage of the metabolism of these bacteria hydrogen atoms on cathodic areas are consumed. The hydrogen aids in the reduction of inorganic sulfates to sulfides. The depolarization of the protective hydrogen film increases the rate of corrosion. Hadley[7] and Starkey and Wight[10] contributed additional experimental evidence in support of this concept.

Anaerobic bacteria associated with the tubercles of iron bacteria in water mains are in part responsible for the formation of differential aeration cells. In the soil, various groups of bacteria may accelerate corrosion in many ways. Kulman[42] from data on the coexistence of aerobic and anaerobic bacteria and seasonal data presented views on the possible modes of microbiological action. Saprophytic bacteria and fungi decomposing organic residues at or near the pipe surface deplete the oxygen supply in localized areas and thereby set up differential aeration cells. Sulfate-reducing bacteria remove polarizing hydrogen from the pipe. Drying of the soil in summer results in a more general prevalence of aerobic conditions. This favors the activity of sulfur-oxidizing bacteria. The latter increase the acidity of the soil with the possibility of chemical attack on buried metal.

Discussion

Relatively few reports of the occurrence of bacterial corrosion of underground pipe lines have been made in the United States. Most interest in this type of corrosion has been made in the Eastern states. It is quite likely that the full significance of bacterial corrosion is yet to be determined. In those areas in which the symptoms have been systematically sought it has been recognized and correlated with serious corrosion.

Some of the reasons why bacterial corrosion has not been more generally recognized are the following. It is a relatively new concept. It was introduced to American corrosion engineers just before World War II. Military investigations during the war were not given wide notice. A major program of research for more precise detection methods for corrosive soils favorable to bacterial corrosion apparently did not receive the attention it deserved. There may have been some over-emphasis of the microbiological features which was somewhat foreign to the corrosion applications. The mechanism of bacterial corrosion is still imperfectly understood. However, field methods for the detection of bacterial corrosion, especially when supplemented with pipe inspection are adequate. More precise methods suitable for field surveys are in a developmental stage.

Bacterial corrosion is primarily involved with bare areas of pipe exposed directly to corrosive soil action. Significant advances are being made now in the improvement of protective coatings and methods of applying and testing them. When economically justified, the coatings are supplemented with cathodic protection. These protective measures should prevent trouble from bacterial action and shift emphasis from the problems concerned with bare pipe. However, large percentages of the older pipe line systems of public ultilities and industry are neither coated nor cathodically protected so corrosion problems of bare pipe will be a matter of concern for many years. Many companies operating city distribution systems of mains and services find that it is not always economic to coat all new pipe being installed. In some systems cast iron mains are being installed. In others, bare mains are laid in the aerated soils and coated steel in the poorly aerated sections. The bacterial influence requires evaluation along with other factors known to contribute to the corrosiveness of soils.

Conclusion

Various reasons have been suggested to account for the fact that bacterial or anaerobic corrosion remains the least known of the causes of corrosion of iron underground. There is basis for believing that bacterial corrosion is not rare but actually widely distributed. It is probable that much corrosion of this nature has not been recognized. If attention be diverted from the specific biological agent as the primary causative factor or symptom to the physical site and soil conditions with which these specific bacteria are constantly associated a more realistic approach to the corrosiveness of many aggressive soils will result. The important site factors are level or low-lying areas, often adjacent to bodies of water, poorly drained and poorly aerated. The soil texture is dense, organic residues are common, the pH is near neutral and the redox potential is low. The site and soil characteristics are associated with anaerobic soils in which bacterial action contributes to the corrosion process.

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Kel-F Applications in Corrosive Systems*

By L. C. RUBIN and W. O. TEETERS

Introduction

IN CONNECTION with the gas-diffusion program carried out during World War II, a need developed for a material which would withstand highly corrosive substances. Miller and his associates[1] undertook to solve this problem and developed a method for synthesis of chlorotrifluoroethylene and a technique for polymerization of the monomer to oil, wax and plastic materials. The success of these products in the gas-diffusion project applications stimulated interest in their commercial development.

This commercial development was undertaken by The M. W. Kellogg Company and resulted in the production of a series of chlorotrifluoroethylene polymers now being supplied under the trademark Kel-F* which is now available as a thermoplastic molding powder and as a dispersion of this molding powder and as oils, waxes and greases.

Certain Main Physical and General Properties

Plastic grades of Kel-F have high heat resistance are chemically stable, have good electrical properties are nonflammable, give clear to translucent films and have zero water absorption. They are readily molded by extrusion, compression, injection and transfer molding techniques used for other thermoplastic materials.

The oils, waxes and greases, like the high molecular weight plastic, are highly inert chemically, have good electrical properties and are nonflammable, colorless materials.

Commercial Kel-F plastics, possessing the desired mechanical strength, range to well over 100,000 molecular weight.[2] Other properties are:

Specific Gravity	2.1
Specific Heat	0.216 cal/gm.
Thermal Conductivity	1.44×10^{-4} cal/cm²/sec/°C/cm
Thermal Coefficient of Linear Expansion	
—80° to + 20° C.	4.5×10^{-5} in/in/° C.
+20° to +150° C.	7×10^{-5} in/in/° C.
Rockwell Hardness—R Scale	111-115
Tensile Strength, 77° F.	5,730 psi
Tensile Strength (Oriented film)	30,000 psi.

Kel-F oils, waxes and greases are substantially lower moleclar weight than the plastic. Other properties are:

Specific Gravity	1.9 — 2.0
Kinematic Viscosity at 210° F	1 — 100
Pour Point, ° F.	From below —35 to +135
Viscosity Index	Below 0

Applications of Kel-F

The oils, waxes and greases may be used as lubricants, pump seals and similar applications in highly oxidizing and corrosive atmospheres. They also may be used as plasticizers for the Kel-F plastics when the end use requires a more flexible section than can be obtained with the plastic alone.

Molded Separators

The material is the least subject to cold flow of the commercial fluorocarbon resins. It will distort to some extent, but after the load has been released the percent recovery is high.[3] Its recovery property, combined with stability, inertness and high heat resistance make it an ideal material for use as diaphragms,

ABOUT THE AUTHORS

LOUIS C. RUBIN—Manager, Chemical Manufacturing Division of The M. W. Kellogg Company, has been with the company since 1930. For the past five years he has been concerned chiefly with commercial development and sales of thermoplastics made by Kellogg under the trade name Kel-F. Prior to that he was largely responsible for development of hydroforming, catalytic polymerization and cracking units built by his company. He holds a degree in petroleum engineering from Colorado School of Mines, 1927; MS in chemical engineering from Massachusetts Institute of Technology, 1930. He is author of many papers and holder of numerous patents.

WILBER O. TEETERS—Technical assistant to the vice-president in charge of research at The M. W. Kellogg Company, he has been active in industrial research in solvents, plasticizers and plastics. Much of his time during the past three years has been devoted to protective coatings investigations. He holds a BS from the State University of Iowa, 1930, and MS and PhD in chemistry from the University of Illinois, 1935.

Figure 1

Abstract

A series of exceptionally heat-stable thermoplastic fluorochlorocarbons derived from chlorotrifluoroethylene and commercially available under the trade name Kel-F are highly resistant to a large number of chemicals. Their properties make them particularly attractive for use as thermoplastic protective coatings and in the form of molded separators. Some aspects of the development work and results obtained in solving corrosion problems are presented in this article.

The use of diaphragms of this material in Saunders' type valves has solved many difficult commercial operating and corrosion problems. Suitably designed "O" rings and gaskets have solved gasketing problems in some highly corrosive systems. Other similar applications are being studied.

The application of these coatings to protect metal surfaces exposed to corrosive systems is being studied via dispersions of finely divided plastic in a volatile vehicle. Preliminary data on the vapor permeability of the films prepared from dispersion indicate it to be superior to most other plastic films tested.

The performance of the coatings is dependent to a large extent on the molecular weight of the polymer. Molecular degradation of the polymer during the fusion operation and subsequent heat aging is influenced by various metals; in some cases excessive degradation has resulted.

The coatings have been tested in the laboratory with a large variety of corrosive materials and numerous field tests are under way.

★ A paper presented at the Eighth Annual Conference, National Association of Corrosion Engineers, Galveston, Texas, March 10-14, 1952.

* Registered trade-mark for The M. W. Kellogg Company's trifluorochloroethylene polymer.

gaskets, "O" rings and other types of separators. Excellent results on performance tests have led to the commercial fabrication of these items which are used in chemical processing equipment exposed to corrosive systems.

Gasketing on flat flanges was among the early applications of this material. The gaskets for flat flanges are made by cutting from flat compression molded sheets. More recent applications have been in the form of solid and jacketed "O" rings and gaskets used in highly oxidizing atmospheres such as white and red fuming nitric acid. The jacketing has been used when the service required a relatively soft but resilient seal. Such seals are operable over a wide temperature range, thus taking advantage of the elastic properties of the resilient core and its chemical inertness.

Kel-F diaphragms in diaphragm pumps have made possible the use of this type pump in highly corrosive systems where they were useless with any other diaphragm material.

Corrosion resistant fittings and small containers have been made by compression and transfer molding while tubing of wide range of diameters has been made by extrusion. Such equipment has proved highly successful in handling corrosive liquids and gases.

Another highly successful use is in diaphragm valves. Inasmuch as Kel-F is chemically inert to inorganic acids, alkalies and salt solutions and only slightly swelled by a few organic materials, installations have given excellent results. In some services where the best diaphragm materials formerly available have a maximum life of 24 hours, Kel-F has given service 9 to 15 months. Table I gives a few typical services where Kel-F valves have turned a bad operating headache into a routine operation.

TABLE I

Diaphragms 1/16-Inch—Kel-F P-25 Installed in Valves

MATERIALS TESTED	Temperature	Pressure
1. 20-25 percent HNO_3 + abrasive solids	180-200° F.	15-20′ head
2. 25 and 70 percent H_2SO_4	Varied	....
3. Conc. HCl—Benzene impurity	190° F.	....
4. Chromic Chloride	131° F.	15 lbs.
5. Chromate—Chlorinated Hydrocarbon mixture	70° F.	15 lbs.
6. Chlorinated Aromatic Hydrocarbon	Varied	....
7. Na_2CO_3	194° F.	50 lbs.
HCl—S percent	212° F.	50 lbs.
H_2SO_4 at pH3	68° F.	50 lbs.
H_2SO_4—39 percent	108° F.	50 lbs.
H_2SO_4—31 percent	68° F.	50 lbs.
Chlorinated Aromatics	....	50 lbs.
8. Acetyl Chloride, Acetic Acid—Cl_2, HCl	300° F. max.	....
9. Aromatic Solvents and Ketones	230° F.	....
10. Benzoyl Chloride—100 percent	80° F.	20 lbs.
11. Ti Cl_4	275° F.	100 lbs.

Data courtesy of Grinnell Co., Inc.

Another highly successful use is in diaphragm valves. Inasmuch as Kel-F is chemically inert to inorganic acids, alkalies and salt solutions and only slightly swelled by a few organic materials, installations have given excellent results. In some services where the best diaphragm materials formerly available have a maximum life of 24 hours, Kel-F has given service 9 to 15 months. Table I gives a few typical services where Kel-F valves have turned a bad operating headache into a routine operation.

Protective Coatings

The chemical inertness and mechanical properties of Kel-F plastic make it extremely interesting as a protective coating material. In view of this, a number of equipment lining methods are under development. These are based on using the plastic in the form of 1) a thin extruded sheet 5 to 10 mils thick, 2) the plastic impregnated into a supporting material, 3) compression molded sheets 30 to 50 mils thick, and 4) dispersions for coating directly.

The plastic is available as layflat tubing with wall thickness from as little as two mils to a maximum of 10 mils and layflat widths up to 14 inches. This material can be cut out to conform to any desired pattern and either heat sealed or electronically sealed to make a container that can then be placed in the desired vessel and serve as the protective lining. This method is satisfactory for small containers but becomes cumbersome when large vessels are involved. It has the further drawback of being subject to damage during installation.

Experimental containers have been made and tested in which the material was impregnated into a supporting material on one side while the other side was bonded to the container wall. This has proved a feasible method of making corrosion resistant containers.

Sheet stock of Kel-F in thicknesses of .030-inch to .040-inch up to 32 inches square is now available. With such sheets, it is possible to form and heat seal a continuous liner in a vessel and have it sufficiently stiff to be largely self supporting.

The dispersions were developed in order to provide a means for applying Kel-F to materials and equipment not amenable to conventional plastic molding. Two dispersions are commercially available, N-1 and NW-25. N-1 contains 20-30 percent plastic dispersed in an organic thinner and NW-25 is a similar dispersion containing 27-40 percent solids. The latter dispersion is preferred when coating objects where it is advantageous to have the discrete particles held more firmly to the surface prior to fusion. Where sharp corners are encountered and one wishes to reduce creeping to a minimum, NW-25 is recommended.

The dispersions may be applied by either spraying or dipping the object to be coated. Customary care should be exercised in cleaning the surface to be coated. After application of the dispersion, the organic thinner is evaporated leaving the white powder covering the surface. The discrete particles are fused

TABLE II[4]

SAMPLE	Film Thickness	P=Constant x 10^{-9} Constant for Water*
Kel-F (Dispersion)	3.0 mils	3.80
Kel-F (Dispersion)	Thick	0.09
Kel-F (Extruded)	3.0 mils	3.50
Kel-F (Pressed)	Thick	0.07
Cellophane (TAPPI standard)	1.50 mils	47.00
Polyethene	1.60 mils	21.00
Pliofilm (TAPPI standard)	3.20 mils	13.00
Saran	1.00 mils	1.35
Waxed glassine	1.80 mils	4.50

* Through 1 mm. thickness—cm^3/sec./cm^2/cm. Hg. differential.

TABLE III

Degradation on Coating and Aging

Initial Molecular Weight of Kel-F in Dispersion—115,000*

SANDBLASTED METAL PANEL	Mol. Wt. Following Application	Mol. Wt. After 175° C Heat—9 Weeks
Aluminum	100,000	100,000
Magnesium	100,000	95,000
Carbon Steel	100,000	95,000
Stainless Steel	103,000	100,000
Black Iron	100,000	94,000
Monel	86,000	85,000
Copper	85,000	84,000

* Approximate figures based on viscosity measurements. Kel-F loses all mechanical strength and plastic properties when the molecular weight drops much below 55,000.

by heating the object to 250 degrees C at which temperature the white powder slowly changes to a clear transparent film. Each coat properly applied will measure 1.5-2.0 mils in thickness. Several coats are recommended for a standard protective film. Following the application of the final coat, an extended bake at 250 degrees C is desirable in order to flow the material to a smooth glossy finish.

For protection against corrosive chemicals and fumes, film permeability is an important factor. The characteristic properties of the films produced by coating from dispersions followed by fusion, have been found comparable to those formed by extrusion or compression molding. Data on permeability have been obtained according to the procedure reported by Doty, Aiken and Mark.[4] The permeability constant for water through 3-mil films is of the order of 10^{-9} (Table II). This is at least a factor of ten less than for other films with the exception of Saran and waxed glassine films. Thicker films show greatly decreased permeability beyond that expected for true diffusion.

In order to obtain optimum performance, it is essential to avoid excessive degradation of the polymer. The plastic alone degrades very slowly at 250 degrees C, one sample going from an approximate 103,000 to 98,000 molecular weight in 72 hours. Table III points up the fact that dispersions may be applied to a large number of metals without excessive degradation and without loss of desirable mechanical properties. Four separate coats of dispersion were applied to the selected metals, each coat baked at 250 degrees C with a final bake at 250 degrees C for each coated panel. The panels were then heat aged for nine weeks at 175 degrees C with negligible additional degradation.

Maximum degradation of Kel-F film occurred during the fusion on copper and Monel metals. The adhesion of the film to copper is very poor and frequently the film separates from it during the final bake. Oxidation of copper at fusion temperatures destroys the mechanical adhesion and presence of copper halide at the copper-Kel-F film interface indicates some chemical degradation. Therefore, copper can not be successfully coated and caution should be exercised also in coating copper bearing alloys.

Chemical Resistance

The action of chemicals on the materiel is divided into three classes and may be briefly indicated as follows:

1) Reaction with chemicals—examples are molten sodium and aluminum powder or aluminum chloride at elevated temperatures;

TABLE IV

Film Performance with Various Reagents

5-Mil Films from Kel-F N-1 Dispersion

REAGENTS	Metal	Temperature	Hours With No Effect On Film or Metal*
HCl (25 percent)	Carbon Steel	Reflux	200
HNO_3 (30 percent)	Carbon Steel	Reflux	200
HNO_3 (White fuming)	Carbon Steel	Room Temp.	10,000
HNO_3 (White fuming)	Aluminum	Room Temp.	2,660
H_2SO_4 (25 percent)	Carbon Steel	Reflux	200
Oleum (20 percent)	Carbon Steel	80° C.	200
KOH (25 percent)	Carbon Steel	Reflux	200
Conc. Brine	Carbon Steel	Reflux	200
HSO_3Cl	Carbon Steel	Room Temp.	2,880
NaOCl (5 percent)	Carbon Steel	Reflux	200
Glycerin	Carbon Steel	100° C.	200
Acetic Acid (Glacial)	Carbon Steel	Reflux	200
Methyl Ethyl Ketone	Carbon Steel	Reflux	200
Benzene	Carbon Steel	Reflux	200

* No failure noted. Shutdown after indicated hours.

2) Swelling action of chemicals—a few reagents such as halogenated organic compounds, ketones, ethers and chlorine are absorbed by the plastic;[5]
3) Solvent action of chemicals—such classes as chloro-fluorocarbons and substituted benzotrifluorides form low concentration high viscosity solutions at high temperature.

Class 2 concerning the swelling action of chemicals is important where thin films are used. It has been found that certain organic chemicals, as for example benzene, methyl ethyl ketone, etc., swell 5-mil Kel-F film on metal surfaces at elevated temperatures. This eventually leads to lifting of the film and loss of adhesion. It should be pointed out that this detrimental effect of these reagents is not observed in most cases where molded materials such as 1/16-inch diaphragms are used.

Kel-F protective films have proved very satisfactory in a large number of corrosive systems, a few of which are listed in Table IV. Data for Table IV were obtained in the laboratory for 5-mil films applied to the selected metal surfaces. The specimens were exposed to both the liquid and vapor of the reagents under test.

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Discussions

Effect of Heat Treatment and Related Factors on Straight-Chromium Stainless Steels by F. Kenneth Bloom. *Corrosion*, Vol. 9, No. 2, 56-65 (1953) Feb.

Discussion by Richard S. Treseder, Shell Development Co., Emeryville, Cal.:

Mr. Bloom is to be complimented on presenting such a wealth of information on a subject of current interest to so many of us. This paper serves to emphasize a point often overlooked—that when we talk of 12 percent chromium steel, we're talking not of a single alloy, but of a number of complex materials subject to significant changes in mechanical and corrosion properties depending on both chemical composition and heat treatment. This has been brought out in recent work on sulfide corrosion cracking in which some annealed alloy steels, including 12 percent chromium steel, were appreciably more resistant to sulfide corrosion cracking than the same alloys in the hardened condition.

Mr. Bloom's comments would be appreciated as to what variations in physical properties, such as hardness and impact strength, could be expected in commercial practice with some specfic item such as Type 410 stainless steel valve stems, heat treated to what might be considered optimum properties of service.

Reply by F. K. Bloom:

In the case of bar stock which will be heat treated by the fabricator to some specific hardness range before going into service, it is always a good practice to advise the producer of this so that an analysis suitable for the application can be selected. The reason will be clear if it is appreciated that these grades are used in a variety of applications where the emphasis may be on needs other than response to heat treatment and which, as is often true of flat rolled products, require an analysis with low carbon content. Material furnished by our company, when specified for valve stem application, will be capable of hardening to a minimum of Brinell 375. After hardening from 1800 degrees F and oil quenching, it can be tempered consistently within a narrow hardness range such as Brinell 200/240 or Brinell 269/321. Suitable tempering temperatures and times can be selected from the charts given in Figures 3 and 4 of the text. Both hardness ranges have been used for valve stem application. Impact strength depends on the size of material being tested. Many hundreds of tests on 1-inch round bars of Type 410 heat treated to a Brinell hardness range of 217/248 show an average Izod impact strength of 90 foot pounds. All values fall within ±15 foot pounds of the average.

Discussion by C. Kenneth Eilerts, Bureau of Mines, Bartlesville, Okla.

While the Bureau of Mines was cooperating with the Condensate Well Corrosion Committee of the National Association of Corrosion Engineers in testing steels and alloys selected for corrosion resistance to the action of gas-condensate fluids, some results were obtained that are of interest in connection with Mr. Bloom's paper. In addition to other tests, the effect of heat treatment on the rate of corrosion of chromium-alloyed steels was investigated because these steels are heat-treated to develop the physical properties required of tubing and Christmas-tree fittings. Coupons of 9-percent chromium-steel plate and 12-percent cast chromium steel were hardened and tempered in accordance with the schedules in column 1 of the attached table. Coupons of the steels then were subjected to test in aqueous solutions of propionic acid and carbon dioxide at 130 degrees F. The rates of corrosion shown in the table are averages for exposure periods of 7, 28 and 70 days.

The NACE coupons of 9-percent chromium steel that were submitted to corrosion tests in both field and laboratory had been furnace-cooled from 1575 degrees F and had a Brinell hardness of only 151. Coupons of this steel were heat-treated in an electric furnace to provide six sets of samples with hardness numbers ranging from 145 to 334 Brinell. All specimens were air-hardened from 1700 degrees F and drawn to the temperatures indicated. The coupons of 9-percent chromium steel used in obtaining the corrosion-test results shown opposite the tempering temperature 1700 degrees F were subjected to test in the air-hardened state without tempering.

Except for the coupons furnace-cooled from 1700 degrees F (designated 1700 FC in the attached table), the results from tests in propionic acid indicate that tempering did not affect corrosion resistance appreciably. Both 7- and 28-day test results show, however, that the fully annealed steel, with a Brinell hardness of 145, has appreciably less corrosion resistance then the tempered steels. Similar results were obtained by exposing the fully annealed 9-percent chromium steel in carbonic acid. On the basis of information available from the laboratory tests, the coupons of 9-percent chromium steel (151 Brinell hardness) used in the tests at wells in the field probably had much lower corrosion resistance than they would have had if they had been subjected to the heat treatment that would result from the process of manufacturing well tubing.

The coupons of 12-percent chromium cast steel used in the NACE corrosion tests in the field were normalized and tempered to a Brinell hardness of 210. This metal showed excellent corrosion resistance

Effect of Heat Treatment on the Corrosion Resistance of Chromium Alloyed Steels

1	2	3	4	5	6	7	8	9	10
Tempering[1] Temperature, °F.	Properties on Basis of Heat Treatment		Measured Hardness, Brinell	Average Rate of Corrosion During Indicated Period of Continuous Exposure, m.d.d.					
				Propionic Acid			Carbonic Acid		
	Yield Point, p.s.i.	Hardness, Brinell		Days, 7	Days, 28	Days, 70	Days, 7	Days, 28	Days, 70
Chromium Steel, 9-Percent									
1,700[2]	151,500	400	291	1.26	0.82	0.46	3.5	3.9	0.53
1,000	160,500	427	334	1.00	2.4	.31	3.8	2.9	.62
1,100	115,000	303	233	1.20	.78	1.73	5.8	4.0	.75
1,300	86,250	234	200	1.10	.98	.60	6.1	4.9	.86
1,400	71,400	212	178	1.03	2.3	.23	7.2	5.6	.97
1,700[FC]	58,500	170	145	4.2	5.4	1.26	21	21	7.4
Chromium Cast Steel, 12-Percent									
900[3]	143,000	350	428	....	....	....	0.30	0.20	0.13
1,000	109,000	278	397	....	....	....	.32	.24	.10
1,100	94,000	241	277	....	....	....	.42	.40	.06
1,200	87,000	225	245	....	....	....	.58	.33	.13
1,300	83,000	218	231	....	....	....	.61	.32	.20
1,450[FC]	.....	...	206	....	....	....	.68	.32	.20

[1] All pieces air-cooled after tempering, except as noted.
[2] All pieces of 9-percent chromium steel air-hardened from 1700° F.
[3] All pieces of 12-percent chromium steel oil-quenched from 1825° F.
[FC] Furnace-cooled from tempering temperature.

in field and laboratory tests and it was interesting to determine whether modification of the heat treatment would appreciably change the resistance of the alloy steel to corrosion by carbon dioxide. The included table shows the results of hardness and corrosion tests on pieces of the metal quenched in oil from 1825 degrees F and drawn to the temperatures indicated. On the basis of 7-day exposure tests, the rate of corrosion of the metal increases as the hardness decreases from 428 to 206 Brinell. Similar trends are indicated by results of the 28- and 70-day tests. However, the highest rate of corrosion of a tempered specimen of the chromium steel was insignificant compared with the rates of corrosion of less resistant steels and the test results indicate that 12-percent chromium cast steel can be heat-treated to attain physical properties corresponding to a wide range of hardness values without changing appreciably its high resistance to corrosion by propionic and carbonic acids.

It was not possible to measure the yield point of the tempered coupons and data in columns 2 and 3 of the table show what properties usually are obtained in the respective steels when they are heat-treated as indicated. It was possible to measure the hardness of the tempered coupons and data in column 4 can be compared with those in column 3 to estimate the yield-point strength attained by tempering the corrosion-test coupons. The data of Armstrong and Brophy[1] and Newell[2] were used for indicating the physical properties of 9-percent nickel and chromium steels. Data provided by Juppenlatz[3] were used in estimating the properties of the tempered 12-percent chromium steel.

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Reply by F. K. Bloom:

The data presented by Dr. Eilerts, as he notes, do not show any consistent relation with varying tempering temperatures. It is noticeable, however, in the case of the longer time tests on the 9-percent chromium steel in proprionic acid that there is a trend to somewhat higher rates for material tempered at 1000 degrees and 1100 degrees F, as might be expected. The general scatter of the figures suggests the possible presence of some other variable more potent in effect than heat treatment.

The rather high rates observed for the samples furnace cooled from 1700 degrees F is interesting. It is likely that cooling very slowly from such a high temperature has resulted in the formation of a lamellar pearlite in the structure. This treatment and structure are not usually considered desirable for high chromium alloys. We have observed that this structure is attacked very quickly with usual metallographic etching reagents, which suggests poor corrosion resistance.

The data on cast 12-percent chromium steel should be of value to users of these steels for well head equipment as they indicate that this steel possesses excellent corrosion resistance when tempered over a wide hardness range.

Discussion by Charles F. Lewis, Cook Heat Treating Co., Houston:

Mr. Bloom has done an excellent job of outlining the effects of heat treatment on the various straight chromium steels. I merely want to emphasize a point or two.

Within the published specifications for Type 410 (and 416) there exists two completely different materials. One will heat treat and the other will not. The specifications call for 0.15 maximum carbon, with chromium 11.5 - 13.5. If the piece to be hardened has the carbon on the low side (say under 0.10) and the chromium on the high side (much over 12

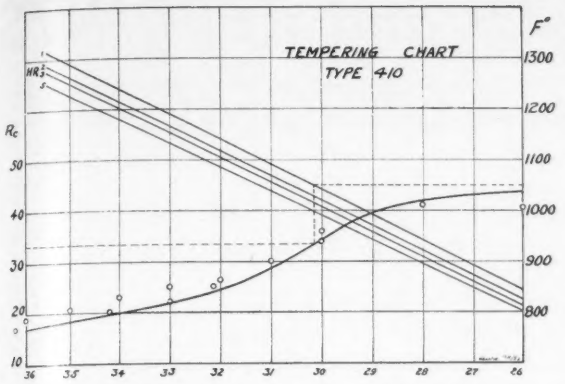

Figure 1—Tempering parameter for construction only.

percent) the piece will not harden at all. If the reverse situation is present the part will heat treat beautifully to a hardness commensurate with the actual carbon content. The metallurgist explains this anomaly by pointing to the existence of the gamma loop for certain regions of carbon-chrome balance. Always let your supplier know whether you intend to heat treat or not so he may pick a heat to fit your needs.

One characteristic of the straight chromium steels in general and Type 410 in particular is illustrated in the author's Figure 2, As the tempering temperature increases the hardness does not drop a great deal until a temperature of about 900 degrees is reached and then it drops very rapidly. Quite often resistance to corrosion is sacrificed in the interest of machining after heat treatment and a hardness is specified in the neighborhood of 300 Brinell. With the slope of the curve so steep in this region it is very difficult indeed to meet a reasonable tolerance bracket of hardness. The author offers the Holloman-Jaffee Tempering Parameter scheme as a solution to the problem. This is sound advice.

The accompaning figure is the form in which we have used the parameter idea in our own shop for about two years. The curve was plotted statistically from published data and we have found it very helpful. The circles are the author's data after conversion from Brinell using charts of the Wilson Mechanical Instrument Company. It shows quite good agreement within the author's observations.

I believe this chart is self-explanatory—the dotted line indicating that a temper at 1050 degrees for one hour should result in a hardness of about 33 Rc. The same result could be obtained by tempering for five hours at 1000 degrees.

Reply by F. K. Bloom:

Mr. Lewis has developed a most ingenious means of combining tempering parameter data into a single chart. His chart should be very useful to everyone engaged in heat treating Type 410. Using a hardness conversion table developed specifically for this grade, we find that his tempering curve corresponds identically with the one in Figure 3. This is a particularly encouraging observation since it is understood that Mr. Lewis's data were taken from a variety of sources in the literature. It is ample demonstration that the straight-chromium alloys of normal analysis will respond to heat treatment in a consistent manner.

ERRATA

Statistics—A Useful Tool for the Examination of Corrosion Data. By Charles F. Lewis, Cook Heat Treating Co., Houston. *Corrosion*, **9**, No. 1, 38-42 (1953) Jan.

Page 38, column 1, paragraph 3, change the first line to read:

Argument is confined to the situation in which

substituting the word "confined" for the word "continued."

Page 39, column 2, paragraph 1, fourth line, change to read:

lacian curve. Its properties are well known and form

Page 41, column 1, footnote with double asterisk, change to read:

**Hold the paper horizontally at eye level and squint down through the points with one eye.

Page 41, column 2, line 7, change to read:

adding about .59 percent iron this could be expected.

changing .52 to .59.

Page 42, column 2, paragraph 1 substitute the following for that portion beginning with the word "average" in the line immediately above the equation and ending with the words "might be pub-" in the second line beneath the equation:

average, for the iron-free data

$$\sigma_{x^-} = \frac{21.2}{\sqrt{4}} = 10.6 \text{ mils}$$

and $1.645\ \sigma_{x^-} = 17.44$ mils

which is 50 percent of the normal expectancy of 35 mils penetration per year. Final results might be pub-

(**Author's Note:** The value σ_{x^-} as shown in the original article on Page 42 is in error. Having dropped one reading there are now only four remaining data. Thus the denominator should be $\sqrt{4}$ instead of $\sqrt{5}$. The corrected statement is given above.)

Page 42, column 2, for first footnote, substitute the following:

*This is sometimes rounded off at 5/3.

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TP-2 First Interim Report on Galvanic Anode Tests
Publication 50-2
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1951—January, February
1952—March

Indices to Corrosion technical literature have been published as follows:
5-Year Index, 1945-49 inclusive and Index to Vol. 6, 1950 ..... December, 1950
Index to Vol. 7 ..... December, 1951
Index to Volume 8 ..... December, 1952

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NATIONAL ASSOCIATION of CORROSION ENGINEERS

HOUSTON **1061 M & M Building** **TEXAS**

NACE News

Cooling Water Corrosion Committee Formed

78 Attend Initial Southern New England Technical Meeting

Eighteen NACE members and 58 guests attended the first technical meeting of the newly formed Southern New England Section February 4 in the auditorium of the Southern New England Telephone Co., New Haven. Chairman Fred Meyer opened the meeting at 8:10 p.m. with a description of the organization of the section.

E. A. Johnson, chief engineer of the Southern New England Telephone Company and chairman of the General Electrolysis Comm. of the State of Connecticut welcomed the group.

Kenneth H. Roll, North East NACE Region vice-chairman extended greetings from national association officers.

T. P. May of The International Nickel Co., Inc., New York presented the Inco motion picture "Corrosion in Action" describing the work that went into the preparation of the picture.

Plans were made for a meeting April 1 at Hartford.

NACE MEETINGS CALENDAR

March ...

3—Houston Section. Joint meeting with ASM. Frank LaQue, speaker.

5—Pittsburgh Section. Corrosion of Water Mains and Water Distribution Systems, speaker to be named.

17—Cleveland Section. The Use of Plastics in Corrosive Environments, speaker to be named.

31—Southwestern Ohio. Protective Coatings, C. G. Munger, Amercoat Corp.

April

1—Southern New England Section.

2—Pittsburgh Section. Metallizing by Howard Vanderpool, metallizing Engineering Company, New York.

14—Houston Section. University night.

21—Cleveland Section. Water Treatment for Corrosion Prevention.

28—Southwestern Ohio Section. Trip through Middletown Division, Armco Steel Corp. Dinner meeting, cocktail Lounge, Manchester Hotel, Middletown, Ohio.

Gulf Coast Group to Coordinate Industry Studies of Problem

Coordination of a cooperative study of cooling water corrosion in Gulf Coast industries is the aim of a new NACE technical committee, tentatively formed at a meeting February 10. The group met at the Ben Milam Hotel, Houston. Twenty-two members of the National Association of Corrosion Engineers representing twelve Gulf Coast chemical and petroleum companies attended.

The committee, designated Technical Practices Committee 8A on Corrosion by Gulf Coast Cooling Waters, elected temporary officers as follows: Charles P. Dillon, Carbide & Carbon Chemicals Company, Texas City, chairman; W. B. Broks, Dow Chemical Company, Freeport, Texas, vice-chairman and A. S. Krisher, Monsanto Chemical Company, Texas City, secretary. Appointed by Chairman Dillon were R. V. Comeaux, Humble Oil & Refining Company, Baytown, Texas, chairman of a committee on by-laws and membership; A. R. Pettyjohn, Carbide and Carbon Chemicals Co., Texas City, chairman of a committee on recirculation systems; Edward Layman, Diamond Alkali Company, Pasadena, Texas, chairman of a committee on once-through systems.

J. L. Ragan, Celanese Corporation, Bishop, Texas, was named chairman of a committee on test and inspection procedures.

Future meetings of the group were scheduled.

DONALD B. GOOD

Funeral services were held at Tulsa, February 9, for Donald B. Good, chief engineer of the Tulsa Division, Texas Pipe Line Company. He was 42 years of age. A native of El Campo, and formerly a resident of Houston, Mr. Good moved to Tulsa in 1933. He was a graduate of Rice Institute, Houston and attended Harvard and Massachusetts Institute of Technology.

He was a lieutenant commander in World War II, a frequent contributor of technical material to magazines and was a member of several engineering associations, including NACE.

His survivors include his widow, a daughter and four brothers.

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Requests for additional copies of Corrosion should be addressed to Central Office, NACE, 1061 M & M Bldg., Houston 2, Texas. Single copies are sold to members at 50c each and to nonmembers at $1 each. A list of exhausted issues is published frequently during the year in Corrosion.

Polyvinyl Chlorides Is Topic at Boston

Greater Boston Section held its first 1953 meeting February 4 at Hotel Beaconsfield, Brookline, Mass. The social hour, dinner and talk were attended by 54 members and guests.

Kenneth Chamberlain of H. N. Hartwell & Son, Inc., spoke on "Application of Rigid Polyvinyl Chlorides to Combat Corrossion."

On May 6 the section will hold its annual meeting at which time committee reports will be presented and officers elected. Scheduled for presentation at this meeting is a talk "Equipment Design and Corrosion Prevention," by F. L. LaQue, of The International Nickel Co., Inc., New York.

Philadelphia Hears Two Microbiological Corrosion Discussions

Discussions on microbiological corrosion and new developments in inhibitors were scheduled for the February 13 dinner meeting of Philadelphia Section at the Poor Richard Club.

The program included a discussion on "Man Against Microbes of Corrosion" by Robert L. Starkey, Professor of Microbe Biology, Research Specialist in Microbe Biology at the College of Agriculture, New Jersey Agricultural Experiment station. Dr. Starkey holds a PhD from Rutgers. Paul H. Cardwell, laboratory director of Dowell Inc., had as his topic "Recent Developments in Corrosion Inhibitors." He is a University of Michigan graduate.

Pittsburgh Section

John J. B. Rutherford of The Babcock and Wilcox Tube Company, Beaver Falls, Pa. spoke to Pittsburgh Section February 5 on "Corrosion in Heat Exchangers." A gratuitous dinner was provided by companies supporting NACE.

New York Section

Persons present for the January 22 dinner meeting of Metropolitan New York Section had many questions regarding confounding reactions they had experienced to ask the speaker, F. L. LaQue, head of the Corrosion Engineering Section of The International Nickel Co., Inc. Mr. LaQue spoke on "Some Apparent Anomalies in Corrosion" to 93 members and guests at Schwartz' Restaurant.

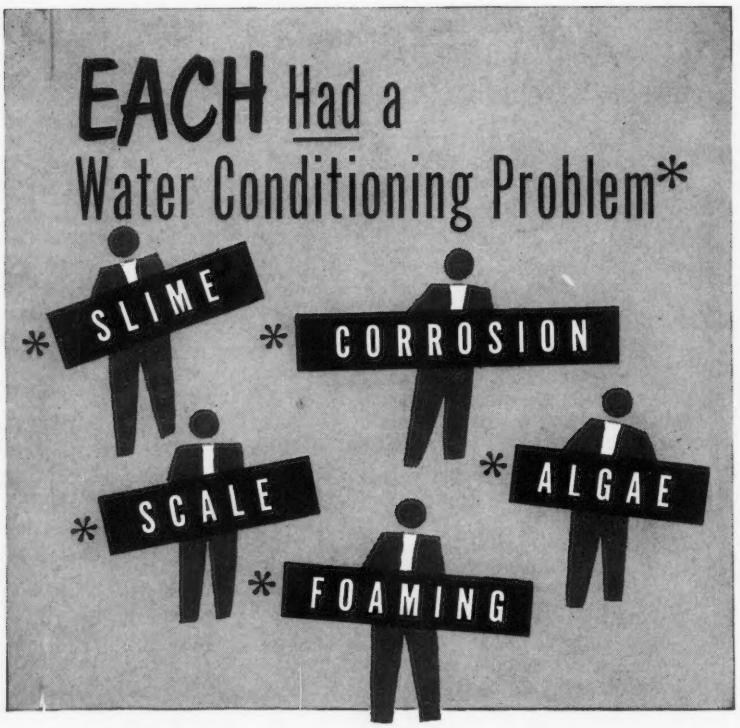
Newly elected officers of the section were installed.

Jacksonville Section Attacks Three of Its Corrosion Problems

The newly organized Jacksonville, Florida Section stepped right into the middle of three corrosion problems interesting to its members at its first meeting. The section named Dwight H. Hibbard of Southern Bell Telephone & Telegraph Company as chairman of a committee to coordinate corrosion control measures initiated by operators of underground plant. Consideration was given also to organization of two technical committees, one to consist of representatives of the pulp and paper industry and the other representatives of the phosphate industry.

The organization meeting, held February 4 at the Mayflower Hotel Jacksonville, was featured by the election of officers. Henry T. Rudolf, Atlantic Coatings Co., Inc., was named chairman and P. E. Alexander, Dozier & Gay Paint Co., secretary-treasurer. Arthur B. Smith of Amercoat was named Corporation chairman of the program committee and Tom W. Bostwick chairman of the membership committee.

The underground corrosion committee to be headed by Mr. Hibbard will consist of representatives of local utilities who will coordinate the corrosion control measures of the several companies. The other two technical committees are expected to have members from the interested industries.



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Cleveland Section Presents Television Program January 25

Cleveland Section NACE presented a television program about corrosion engineering January 25 over station WNBK, Cleveland. The program was one of a series called "Adventures in Engineering" sponsored by Cleveland Technical Societies Council on Sunday afternoons in an effort to interest high school students in the engineering profession.

C. N. Detrick, Cleveland NACE Section chairman introduced Dave Rodgers, a student at University School to three other NACE members, Robert C. Weast, R. W. Davis and Oliver Henderson. Dr. Weast, associate professor of chemistry at Case Institute of Technology, gave a laboratory demonstration of several principles of electrochemical corrosion. Mr. Davis, metallurgical consultant, explained the various ways in which corrosion attacks buried structures, vehicles, ships, factory equipment and other metallic articles.

Mr. Henderson of The Ohio Bell Telephone Company described the methods and materials used to control corrosion. They included an array of rectifiers, magnesium anodes, protective coatings, inhibitors and samples of corrosion resistant materials.

Stainless Steel Piping Corrosion Covered at Chicago Meeting

"Corrosion Resistance of Stainless Steel Piping" was the subject of a talk by Barclay Morrison of Carpenter Steel Company, Union, N. J., before members of Chicago Section January 20. The regular monthly dinner meeting at the Chicago Engineers Club was attended by 50 members and 30 guests.

Mr. Morrison divided the corrosion of steel pipe into five categories: 1—General. 2—Galvanic. 3—Pit type. 4—Intergranular. 5—Stress corrosion. He discussed the kind of corrosion that would occur in the presence of excess hydrogen or oxidizing ions and the alloys which would be useful under various circumstances. He indicated he was convinced considerable money could be saved through the use of thin walled corrosion resistant pipe instead of heavy pipe including extra wall thickness as a corrosion allowance.

Southwestern Ohio Discusses Conference

An outline and review of the program to be given at the NACE Chicago Conference March 16-20 at the Sherman Hotel was given to 29 members and guests of Southwestern Ohio Section January 27. The meeting was held at Shuller's Restaurant, Reading, Ohio.

The International Nickel Co., Inc. film "Corrosion in Action," was shown, followed by comments by Roy McDuffie, of the University of Cincinnati.

Uses and Welding of Titanium Discussed At St. Louis Meeting

The Engineers Club of St. Louis was the scene of a joint meeting January 22 of the NACE Greater St. Louis Section and the American Welding Society and Engineers Club of St. Louis. George C. Kiefer, Associate Director of Research, Allegheny Ludlum Steel Corp. spoke on "Uses of Titanium and Methods of Welding." Mr. Kiefer explained the problems experienced with titanium as a metal for corrosive service and also the special techniques required for welding it.

Refreshments were served by the Engineers Club to 162 persons.

Effect of Cathodic Protection Covered at Los Angeles Section

Lester Morris of Amercoat Corporation, Los Angeles, addressed members of Western Region at a meeting January 7 at Los Angeles on "Effect of Cathodic Protection Current on Organic Coating Materials." A discussion followed presentation of Mr. Morris' talk.

Eugene Grizzard, newly elected region chairman, presided over the meeting after 1953 region officers-elect were introduced by W. M. Schilling, outgoing chairman. New officers taking over were Austin Joy, vice-chairman and Robert H. Kerr, secretary-treasurer.

Eastern Wisconsin Officers Are Elected

Officers for 1953 for Eastern Wisconsin Section have been elected as follows: Robert E. Wicen, Chain Belt Co., chairman; Robert A. Huseby, A. O. Smith Corp., vice-chairman; Harold F. Haase, Consultant. All are of Milwaukee.

Protecting Aircraft Is North Texas Topic

M. J. Ruddick, supervisor of Non-Metals Engineering, Chance-Vought Air Craft Corp., will address North Texas Section March 2 at Dallas on "Protection of Naval Aircraft Against Corrosion."

The April 6 meeting will include a talk on the properties of plastic pipe by W. M. Thornton, The Atlantic Refining Co., Dallas.

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Manuscripts of material on corrosion are accepted without invitation for review by NACE. Authors are advised to secure in advance of preparing their manuscripts a copy of the publication "Guide for the Preparation and Presentation of Papers," sent free.

Barrett Is Tulsa Section Chairman

Jack P. Barrett, Stanolind Oil & Gas Co., has been elected chairman of Tulsa Section, as was correctly reported in a news story on Page 4 of the February issue. The headline on the story, however, erroneously stated Jack Battle had been elected. Mr. Battle, who is with Humble Oil & Refining Co., Houston, and is chairman of TP-1H on the Corrosion of Oil String Casing, besides being a long time member of Houston Section, undoubtedly would experience considerable difficulty acting as chairman of Tulsa Section, for reasons of distance if no other.

Apologies are offered to both Mr. Barrett and Mr. Battle for this error.

Harry K. Phipps Heads 1954 General Committee

Harry K. Phipps of Central Pipe Lines Division of the Socony-Vacuum Oil Company, Wichita has accepted the post of chairman of the General Conference Committee for the 1954 NACE Conference and Exhibition. The conference will be held at Kansas City in March, 1954.

Keane Accepts Post

C. C. Keane of Great Lakes Pipe Line Company, Kansas City has accepted the post of local arrangements chairman for the 1954 NACE Conference and Exhibition to be held at Kansas City in March.

TP-7 Will Review High Temperature Corrosion Report

A report on high temperature corrosion data accumulated and organized by Technical Practices Committee 7 will be reviewed at the scheduled meeting of the group at Chicago in March. Eleven members of the committee met October 21 at Philadelphia and discussed data accumulated. The committee adopted a scheme for condensing the data, adding information pertaining to corrosion rates and supplementary data respecting tendency to pitting, stress corrosion or intergranular attack.

Introductory information and definitions also are to be added to the draft which will be examined during the annual conference March 16-20.

TP-1D Meets March 4 At Odessa, Texas

NACE Technical Practices Committee 1D on Sour Oil Well Corrosion has scheduled a one-day meeting March 4 at the Lincoln Hotel, Odessa, Texas. Topics to be discussed include corrosion in the vapor space of the tubing-casing annulus, inside of tubing and new developments in the use of plastic pipe, plastic coatings and inhibitors.

Company representatives have been asked to prepare in advance of the meeting brief reports on the status of these subjects in their respective organizations.

Sudrabin Heads TP-4

L. P. Sudrabin of Electro Rust-Proofing Corp., Belleville, N. J. has accepted the chairmanship of NACE Technical Practices Committee 4 on Minimum Current Requirements for Cathodic Protection. The chairmanship was vacated recently by the death of J. M. Pearson.

TP-17 Agrees on Valid Test on Conductance Of Pipe Coatings

Agreement on a valid test method to determine the conductance of pipe coatings was reached at a meeting, February 9-10, of Technical Practices Committee 17 on "Standardization of Procedures for Measuring Pipe Coating Conductance." The two day meeting, held at Town House, Houston, was presided over by W. E. Huddleston, of Huddleston Engineering Co., Bartlesville, Okla., committee chairman.

Discussions during the session included remarks by Gordon N. Scott, consulting engineer, Los Angeles and Scott P. Ewing, Carter Oil Company, Tulsa, Okla., whose comments principally concerned the nature of valid computations. L. G. Sharpe and E. R. Allen, Jr. of Humble Pipe Line Company, Houston and Lyle R. Sheppard, Shell Pipe Line Company, Houston presented field data.

The concensus was that a valid test method had been outlined and that the committee would be able to make an interim report in the near future.

Pierson Talks on Starch Manufacture

T. H. Pierson of Corn Products Refining Co. was the scheduled speaker at a meeting of Corpus Christi Section February 17. The dinner meeting was set for the Corpus Christi Engineers Club. Mr. Pierson's topic was "Manufacture of Starch for Food and Industry."

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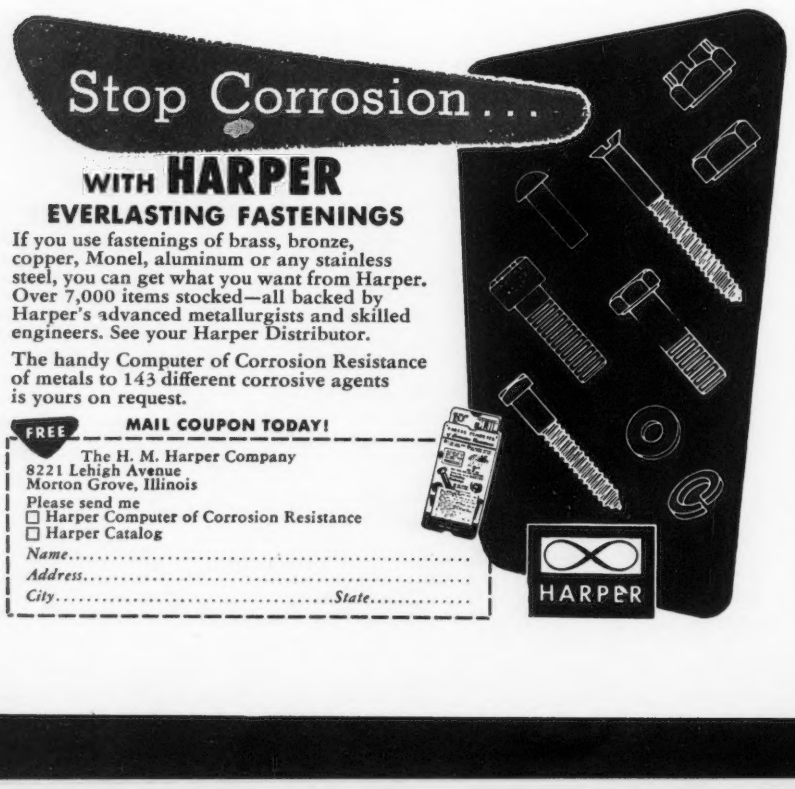
Reprints of technical material printed in Corrosion are not made except on special order. A limited number of reprints of especially interesting material is made on occasion.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New Orleans-Baton Rouge

Officers have been elected as follows by New Orleans-Baton Rouge Section: Jack T. Martin, The Texas Company, chairman; Frank S. Bird, The California Co., vice-chairman; Russell W. Schutt, Shell Oil Company, secretary-treasurer. All are of New Orleans.

Galvanizers to Meet

The annual meeting of the American Hot Dip Galvanizers Association will be held March 19-20 at the Netherland-Plaza Hotel in Cincinnati.

AIChE Plans Meetings

The American Institute of Chemical Engineers will hold a joint meeting with the Chemical Institute of Canada at Toronto April 26-29.

The American Institute of Chemical Engineers' March 8-11 meeting at Biloxi, Miss., will feature presentation of 22 papers.

One symposium will deal with the application of mineral engineering techniques to chemical engineering. Other symposia include fluid mechanics and one on hydrometallurgical processes. General symposia on kinetics of catalytic cracking, and heat transfer are planned also.

Inter Society Committee
CORROSION MEETINGS CALENDAR

Mar. 3-5—SAE National Passenger Car, Body and Materials Meetings, Detroit, Mich. Hotel Sheraton-Cadillac. (Some papers on automobile corrosion.)

Mar. 16-20—Annual Conference and Exhibition, National Association of Corrosion Engineers, Chicago. Sherman Hotel.

Apr. 12-16—The Electro-chemical Society, Spring Meeting, New York City. Statler Hotel.

Apr. 13-16—American Gas Association—Distribution, Motor Vehicles and Corrosion Conference, Chicago. Sherman Hotel.

May 10-15—American Water Works Association—General Convention, Grand Rapids, Mich. (Two papers on corrosion control.)

May 11-14—Midyear Meeting of American Petroleum Institute, Session on Corrosion of Refinery Equipment, New York, N. Y. Commodore Hotel.

June 4-6—Protective Coatings Division Meeting, Annual Chemical Institute of Canada Conference, Windsor, Ont.

June 15-18—American Electroplaters Society, Annual Meeting, Philadelphia. Benjamin Franklin Hotel. (Some papers on corrosion.)

July 20-25—AAAS Gordon Research Conference on Corrosion, New London, N. H.

August—Symposium on Corrosion, Association Committee on Corrosion Research and Prevention of National Research Council of Canada.

Sept. 13-17—The Electro-chemical Society, Fall Meeting, Wrightsville Beach, N. C., Ocean Terrace Hotel.

BOOK REVIEWS

ASTM Standards on Paint, Varnish, Lacquer and Related Products. September, 1952. 6 x 9, paper bound, 781 pages plus XIX. American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. Per copy $5.75.

The eighth edition of the compilation of ASTM standards on paint, varnish, lacquer and related products provides more than 200 specifications, tests and definitions issued by ASTM Committee D-1. Related standards from other committees are included also.

Material covered includes specifications for pigments, drying oils, paint driers, thinners, shellac, varnish, naval stores, lacquer and lacquer materials, traffic paint, bituminous emulsions, paint tests, putty and paint weathering tests. Of the 23 new standards included 16 are methods of test, six are specifications and one covers forms for reporting results of exposure tests on paint.

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Steel Castings Handbook. Charles W. Briggs, Editor. 6 x 9 inches, 511 pages plus v, fabrikoid cover. June, 1950. Steel Founders' Society of America, 920 Midland Bldg., Cleveland 15, Ohio. Per copy $4.00.

This well-illustrated book contains a large quantity of tabulated data and numerous references. It deals with the whole scope of the steel castings industry, enumerating the classes and advantages of steel castings, commercial and industrial applications, design, manufacturing methods, heat treatment, variables affecting the mechanical properties, mechanical properties of carbon cast steels, heat and corrosion resistant cast alloys, austenitic manganese cast steel, physical values pertaining to cast steel, engineering properties, recommendations to purchasers of castings, specifications, definitions of foundry terms and chemical compositions of standard steel.

This revision of the 1941 edition in the chapter dealing with heat and corrosion resistant cast alloys deals generally with the various principal classes of cast metals for corrosive and high temperature service. Typical applications of several principal alloy types are tabulated, and the factors to be weighed in selecting a corrosion resistant alloy are given. General characteristics of the heat resistant alloys are listed and tables are given showing the mechanical properties of principal corrosion resistant alloys at room and high temperatures.

ASTM Meetings Set

The following meetings by committees of the American Society for Testing Materials have been scheduled.

March 17-18—Committee B-5 on Copper and Copper Alloys. American Standards Association headquarters, New York City.

June 29-July 3—1953 ASTM Annual Meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.

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Abstracts published in the Corrosion Abstract Section of Corrosion are indexed according to the system compiled for use with the association's Corrosion Abstract punch cards.

Films Available on Materials for Chemical Process Equipment

Two films designed for showing to engineers and students interested in designing, specifying materials for, installing, operating or maintaining chemical process units have been produced by National Carbon Company, division of Union Carbide and Carbon Corp., 30 East 42nd St., New York 17, N. Y. Running time for the two sound and color pictures is 26 minutes.

"Meeting the Challenge," running time 14 minutes, deals with equipment design and specific applications in modern process industries. The second, "By Way of Experience, running time 12 minutes, depicts proper installation and maintenance techniques of heat exchangers pipe and fittings, pumps, valves, towers and accessories.

Four Exhibitors Added For Chicago Meeting

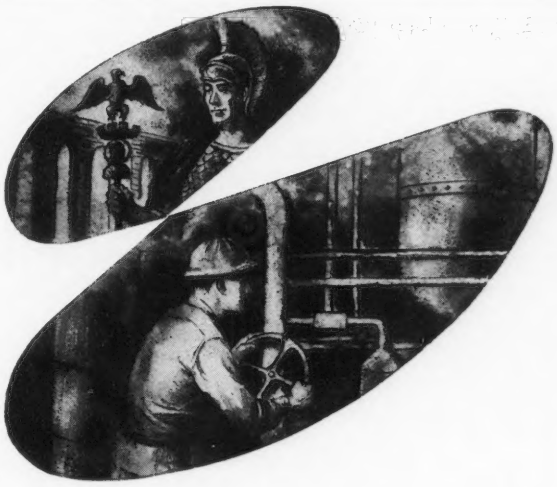
Exhibitors at the Chicago Conference and Exhibition listed since the publication of a list in the February issue of Corrosion are:

Owens-Corning Fiberglas Corp., Toledo, Ohio.

Plastic Engineering & Sales Corp., Fort Worth.

Tinker & Rasor, San Gabriel, Cal.

Wright Chemical Corp., Chicago.



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Preservation, Packaging Discussed at Camden

A roundup of information on current packaging and preservation practice was presented at a two-day Joint Industry Conference on Preservation and Packaging sponsored by General Motors Corp. and R. M. Hollingshead Corp. at Camden, N. J. during November. Papers presented covered thixotropic compounds, peelable coatings, fingerprint remover compounds, government corrosion preventive specifications and general discussions on the theory and application of corrosion preventive measures.

Herbert H. Uhlig, head of the Massachusetts Institute of Technology Corrosion Laboratory defined corrosion and discussed its causes and mechanisms.

Summaries of some of the papers presented follow.

Discussion of Laboratory and Field Experiences with Corrosion and Its Prevention by J. H. Gustafson.
This deals with the methods used for removing fingerprints from bearings before application of rust preventives.

Cold Dip Plastics by M. R. Gatto, R. M. Hollingshead Corp.
Formulation and characteristics of a cold dip strippable plastic are given. Technique of preparations and various operations to secure coatings of various thicknesses are given. Some of the mechanical and chemical characteristics are given also.

Discussion of Thixotropic Compounds, Possible Industrial Application and Comments on Specification MIL-C-5545 by Joseph Carroll, Naval Aviation Experimental Station, Philadelphia.
The navy's experience with thixotropic compounds used to protect against corrosion the insides of engines and other machinery is given. The development of specifications for a heavy oil type preservative is outlined and experience with its use given.

Development of Government Specifications and Simplification Consolidation Programs by G. O. Inman, Rock Island Arsenal.
Criteria used in the development of government specifications of corrosion preventives for the military services are listed. A committee formed to consolidate and simplify government specifications for corrosion preventive coatings has been active in reducing the number of specifications and to unify test methods prescribed. Allocation of specifications so the air force will have fingerprint removers, the army petroleum type rust preventives and the navy cutback preventives has been agreed on.

Walter E. Turner, packaging consultant described the experience of General Motors with strippable ethyle cellulose and cellulose acetate butyrate for the propection of small parts. He also covered new equipment and materials available for use in parts packaging.

Ways Sought to Limit Bimetallic Corrosion Of Power Line Terminals

Ways to prevent bimetallic corrosion which occurs when aluminum and copper components of electrical transmission lines are joined in a salt atmosphere are being studied at Texas Agricultural and Industrial College at Corpus Christi. The project is being managed jointly by the school's department of engineering and the Central Power and Light Company. The tests began in March, 1952.

The outdoor tests currently under way involve exposure of numerous joints of devices being tested on wires through which periodic surges of current are sent. The tested joints are subjected to salt water or spray with the objective of determining which joints and which among the various protective methods are best. Protection for the joints includes, paints, inhibitors, mastics and tapes.

Considerable savings in corrosion losses as well as in initial investment in clamps is expected from development of new clamps. The tests have indicated so far that in clamps copper and aluminum must be separated mechanically to give good service.

O. A. Boyer, Central Power and Light Company distribution engineer; Emerson Korges, assistant professor of engineering at A & I and John E. Dean, formerly engineering professor set up the tests originally. Prof. Dean is now with Colorado A & M college.

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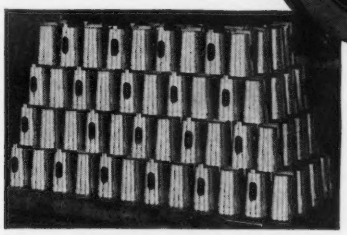
This Monel tube bundle used in an HF Alkylation Unit Dehydrator Reboiler is an excellent example of the use of Monel to resist corrosive chemical attack even at high operating temperatures.



These plugs for 2-inch plug valves used in hydrofluoric acid alkylation service were machined from Monel rod. No. 140 Monel Arc Electrodes are used for overlaying steel plugs in larger valves.

How Monel muzzles HF ...even at high temperatures

Monel lined hydrofluoric acid regenerator column with 1/16" minimum lining of Monel. The two Monel grids are for holding the Raschig rings.

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It does not acquire a scale when exposed to anhydrous HF which makes it especially useful for moving parts having close clearances, such as plug valves and pump rings.

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Studies Show Heat Treatment Restores Resistance at Welds

Scarcity of nickel and the substitution of straight chromium steels for the austenitic chromiun-nickel grades has made the behavior of straight chromium welds of extreme importance. Tests of welding straight chromium steel conducted by Allegheny Ludlum Steel Corp., indicates two things:

1. Lowered corrosion resistance at weld areas; and

2. Corrosion resistance is restored by simple heat treatment at 1450 degrees F.

Tests made on as-welded samples showed that both Type 442 and Type 430 stainless steels were susceptible to rapid attack in the weld area in the Huey boiling 65 percent nitric acid test, the Krupp test, hot nitric-hydroflouric acid test at 180 degrees F, as well as in cold 5 percent sodium chloride solution. When titanium is added to the straight chromium steels, ductility of both fusion and resistance welds is improved. Corrosion resistance is increased in welds made by the resistance method. Fusion welds, however, are not helped by the addition of titanium as far as corrosion resistance is concerned except when titanium equal to eight to ten times the carbon content is present. Samples showed good resistance to the Krupp solution after 48 hours exposure.

Annealing treatments are necessary to restore corrosion resistance to weld areas, even though the steel may contain as much as seven times as much titanium as carbon. When heated to approximately 2300 degrees F, or welding heat, structural changes occur in Types 430 and 442 stainless steels. With 17 percent chromium steel, austenite forms at the grain boundaries of ferrite at elevated temperatures. Since it is relatively unstable, this austenite tends to transform to a constituent similar to martensite upon cooling and forms a hard, brittle envelope around the grain. In as-welded samples, corrosion attack is along a line immediately adjacent to the weld. Treatment of an hour at 1200 and 1300 degrees F, lessens the severity of attack, but marked improvement is not attained until the 1400 degrees F treatment is applied. The corrosion attack is intergranular. When the titanium-to-carbon ratio is seven or greater, better anti-corrosion properties are obtained. This is true when welding is done by the resistance method. However, the improvement titanium provides when other welding methods are used is so slight, it is doubtful that titanium grades of steel will be used for welds other than resistance welding. A detailed technical study on the foregoing can be obtained by writing to "Steel Horizons," 552 Oliver Bldg., Pittsburgh 22, Pa. (Information herein summarized from "How to Increase Corrosion Resistance After Welding," by T. A. Pruger, Allegheny-Ludlum Steel Corp., Pittsburgh. Steel Horizons, Vol. 14, No. 3, 20-23 (1952).

New York University Report Lists Projects Related to Corrosion

Numerous projects likely to develop material of interest to corrosion workers are underway at New York University. The research activities of the institution during 1953 resulted in expenditure of $1,750,000, as detailed in a 32-page report issued December 29, 1952. Copies of the Research Division's annual report are available from the Office of Information Services, NYU College of Engineering, University Heights 53, N. Y.

Projects of corroison interest included: Protective Coatings—The Wet Ground Mica Association's investigation of the effect of platy-shaped extender materials on coating systems in vinyl carriers. Next to be investigated are the value of mica extenders in latex-emulsion coating systems.

Chemical Conversion of Steel Surfaces—Oakite Products, Inc. is sponsoring a project to study the development of chemical conversion to increase paint bonding qualities.

Titanium—New alloys, investigations into grain size and transformation characteristics are being made.

TNT Waste Water—A method is being sought on the processing of TNT waste water to make it suitable for discharge into streams.

Air Pollution—Wind tunnel studies of air pollution problems are being carried out under sponsorship of the Atomic Energy Commission.

Ultra High Strength Steels Seminar Set At Los Angeles

A seminar on ultra high-strength steels for aircraft and automobiles will be held by the Society of Automotive Engineers' Southern California Section at the Western Metal Congress, Los Angeles, March 23-27. Topics will be Materials and Metallurgy, Fabrication and Processing and Design Considerations.

Other seminars are to be held by, ASM, AWS, Society for Non-Destructive Testing, American Foundrymen's Association, and the Metals Branch of AIMME.

Among the papers scheduled of corrosion interest are:

Tuesday, March 24: Resistance of Cast Iron Nickel Chromium to Corrosion in Molten Heat Treating Salts by J. H. Jackson and M. H. LaChance, Battelle Memorial Institute, Columbus, Ohio. Corrosion Studies on Magnesium-Lithium Alloys by P. D. Frost, F. W. Fink and J. H. Jackson, Battelle Memorial Institute.

Wednesday, March 25: Effect of Hydrogen on the Embrittlement of Zirconium and Zirconium-Tin Alloys by W. L. Mudge, Jr., Westinghouse Eelectric Corp., Pittsburgh.

Thursday, March 28: Corrosion by L. B. Golden, Bureau of Mines. College Park, Md.

Case Institute's Paint Short Course Readied

A second short course in the fundamentals of "Paint as an Engineering Material," sponsored by the Department of Chemistry and Chemical Engineering of Case Institute of Technology, Cleveland will be held March 30-April 1 inclusive.

The purpose of the course is to review the theory and practice of coatings engineering with respect to specification and application of organic finishes and with particular reference to the special circumstances that result from recent efforts to evaluate and use the newer types of synthetic resin finishes.

General topics to be considered are: Metal Protection in Severely Corrosive Environments. Special Problems in Paint Application: a) Factors of adhesion of organic coatings; b) causes and remedies of other paint application faults. Testing of Organic Coatings: a) design and interpretations of experiments for field or service testing; b) accelerated laboratory tests.

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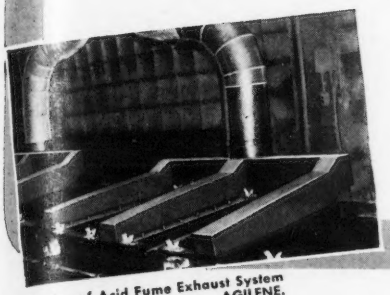

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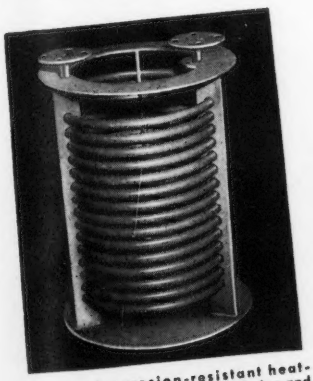

Section of corrosion-resistant heat-exchanger system, using AGILIDE pipe and frame-work of fully welded construction.

AGILENE removable tank-liner, fitted into a plywood case.

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84 Firms Will Have Exhibits at Conference

Eighty-four firms will have exhibits at the Sherman Hotel, Chicago, during the Ninth Annual Conference and Exhibition to be held there March 16-20. Products to be shown include pipe coatings, maintenance coatings, plastic linings and structural materials, steel, nonferrous and alloy pipe, valves and equipment, devices for testing the continuity of coating, systems of cathodic protection, rectifiers and galvanic anodes, inhibitors, pipe wrappings, pumps, couplings, high and low alloy parts, various kinds of equipment, and many other items.

The exhibit will probably be the largest ever to be held in connection with an NACE Conference. There is some liklihood the number of exhibitors may be increased by two or three before the conference opens.

Technical Program

The technical program for the conference will be substantially that reported in the February issue of Corrosion with the exception that the sequence of presentation will be different from the arrangement of the printed abstracts.

Questions from members of the NACE planning to attend discussion sessions are being received at Central Office and are being forwarded to the chairmen of discussions.

Registration will open at noon Sunday, March 15 and will continue from 8 a.m. to 5 p.m. daily through Thursday, March 19.

No technical sessions have been scheduled for Monday, March 16 so the whole day may be devoted to meetings of technical and standing committees. Many meetings of committees will be held during the remainder of the week also.

The annual business meeting will be held on Tuesday, March 17, beginning at 11 a.m. The annual fellowship hour is scheduled to begin at 6 p.m. this same day.

Technical Program Outline

An outline of the technical program follows:

Monday, March 16

Technical and Standing committee meetings.

Tuesday, March 17

9 a.m. Committee meetings. Corrosion principles Symposium. Pipe line Coatings Symposium.

2 p.m. Corrosion by Fresh and Salt Water Symposium. Refinery Industry Symposium.

Wednesday, March 18

9 a.m. Elevated Temperature Corrosion Symposium. Pipe Line Group Discussions.

2 p.m. Power and Communication Industry Symposium. Oil and Gas Production Symposium.

Thursday, March 19

9 a.m. Cathodic Protection Symposium. General Corrosion Problems Round Table.

2 p.m. Pipe Line and Underground Corrosion Round Table. Chemical Industry Symposium, First Session.

Friday, March 20

9 a.m. Chemical Industry Symposium, Second Session. Protective Coatings Symposium.

Discussions to Be Taken

As is the practice of the association submission of written discussions before, during and after the presentation of technical papers will be encouraged. Forms will be provided for this purpose which may be used. The discussions usually are printed in Corrosion, the official NACE monthly publication.

While no preprint copies will be made available by the association, an opportunity will be given press representatives to inspect manuscripts received by the association's Central Office prior to the conference.

NACE POLICY ON DUES IN ARREARS

No member of the association with dues in arrears for three months shall receive publications of the association until such dues are paid. Members in arrears one year shall be dropped automatically from membership.

If your dues are not received at Central Office by the latter part of March, you will be dropped from the list to receive NACE publications and mail. Accordingly the March issue of CORROSION will be the last received by those so dropped.

In order to avoid interrupted mail and missed copies of CORROSION members are urged to remit dues before the deadline. Much work will be eliminated at Central Office if members remit before the date stipulated.

POSITIONS WANTED and AVAILABLE

- **Active and Junior NACE members may run without charge two consecutive advertisements annually under this heading, not over 35 words set in 8 point text type.**
- **Firms seeking employees, regardless of NACE membership, may run an advertisement of the same specifications indefinitely.**
- **Advertisements to other specifications will be charged for at standard rates.**

Positions Wanted

Chemical Engineer, former plant engineer, research chemist, presently engaged formulation, sales, application phenolic, vinyl, copolymer resins. Eight Middle Atlantic states past 5 years handling chemical, paper, textile and allied industries. Earning $12,000. Chemical resin sales preferred. CORROSION Box 53-2.

•

Electrical Engineer, BSEE, 37, married. Veteran. Experience estimating, design, supervision of installation of power, control, telemetering, carrier, radio, instruments, cathodic protection, etc. industrial and gas pipe line. Summary on request. CORROSION Box 53-3.

Positions Available

Chemical Engineer—Familiar with materials of construction and corrosion problems to be technical staff man to evaluate and recommend, also develop methods for mfg. chemical-proof equipment. Advise experience and salary desired. Heil Process Equipment Corp., 12901 Elmwood Ave., Cleveland 11, Ohio.

•

Corrosion Engineers. Positions available for graduate electrical engineers or equal. Previous field and design experience in corrosion mitigation systems required. Extensive travel involved. Salary open. The Hinchman Corp., Engineers, Francis Palms Bldg., Detroit 1, Mich.

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NEW PRODUCTS —Materials—Service—Literature

Lustrex X-820, a carboxyl-containing polyelectrolyte resin is being offered by the product development department of Monsanto Chemical Company's Plastics Division. It is being used successfully as a film-forming vehicle, thickener, binder, emulsifier, protective colloid, dispersing agent, anti-blocking agent and modifier for natural water soluble materials. Suggested fields include latex paints and coatings, printing inks, pigment dispersions, high gloss and grease resistant coatings and others. Samples and full description are available.

•

Neoprene roof coating used to repair cracked canvas or bituminous composition roofs with one coat is being manufactured by Chemical Coatings and Engineering Co., Chester, Pa.

•

Dorber Company, 7741 West Palatine Ave., Chicago 31, Ill. manufactures a dissolved oxygen analyzer for aqueous solutions it claims is not subject to interference by dissolved iron, calcium, magnesium or organic matter.

•

Ceilcrete, a new troweled-on surfacing material, a combination of synthetic resins, inert fillers and pigments, designed as a substitute for acid proof brick, is being produced by Ceilcote Company, 4832 Ridge Rd., Cleveland 9, Ohio. It dries into a hard dense stone-like surface resistant to trucking, foot traffic and abrasion with a rated load carrying strength of about four times that of dense concrete. Applied to walls floors and ceilings subject to attack by corrosives or corrosive atmospheres, it resists solvents, acids and alkalis, is nonsparking, nonslip and has high impact strength. It is available in black and colors and is applied in a single ⅛-inch layer, adding little weight or elevation to floors.

•

Sea-Rite, a salt, which when dissolved in distilled water, produces a liquid comparable to sea water with a density of 1.025, is manufactured by Lake Products Co., Inc., 1252 Grover Road, St. Louis 23 (LeMay) Mo. It is recommended for testing coatings and metals.

•

Iolyte, a Fiberglas reinforced polyester laminate is being used by Schori Process Div., Ferro-Co Corp., 8-11 Forty-Third Road, Long Island City, N. Y. to fabricate tanks and ducts. The company says the laminate withstands higher temperatures than rubber, vinyls, polyethylene and other plastics.

•

Prufcoat Sealer P-25M, composed of selected synthetic resins and a combination of leafing-type metallic pigments, is designed to provide a barrier over all surfaces designed to be coated with vinyl or other synthetic resin coatings. It is recommended by the manufacturers, Prufcoat Laboratories, Inc., 50 East 42nd St., New York 17, N. Y., as a sealer over asphalt, tar and Gilsonite coatings, including mastics. White coatings may be applied over mastic surfaces sealed with the new material, the company states.

•

Eastman Chemical Products, Inc., Kingsport, Tenn. will market products manufactured by Tennessee Eastman Company and the Tennessee Eastman divisions of the Eastman Kodak Company. S. E. Palmer was named vice-president of the plastics department, and D. C. Williams, salesmanager. H. L. Ford was named vice-president of the chemicals department and J. E. Magoffin, salesmanager.

•

Charles R. Bragdon, recently retired from the Interchemical Corp. after over 37 years' service has opened consulting chemical engineering offices at 4 Rock Ridge Road, Larchmont, N. Y. He specializes in work related to manufacturing organic coatings. Mr. Bragdon's experience with Interchemical and its predecessors included direction of research laboratories where he was leader of groups instrumental in developing new pringting inks, resins and enamels. He is a member of several engineering and technical societies, including NACE.

•

Fluorolubes, fluorocarbon materials ranging from light oils to wax-like materials at room temperature, are described in a 16-page bulletin by Hooker Electrochemical Company, Niagara Falls, N. Y. "Fluorolubes, Hooker Bulletin No. 30" is available on request from the company. The materials are credited with high temperature stability and with high resistance to many corrosive chemicals. The bulletin describes in some detail the physical, dielectric and behavior characteristics of the several materials marketed under this name.

•

Properties of weld metals for low temperature service are featured in detail in an article in the Winter 1953 issue of the Alco Products Review, published by the American Locomotive Company, Dunkirk, N. Y.

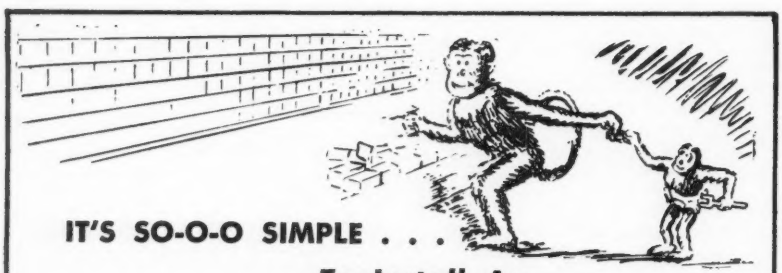
•

Quikupl stainless steel fittings with butyl rubber seals are now available, the manufacturer, Cooper Alloy Foundry, Hillside, N. J. says. Standard seals will continue to be neoprene, but butyl seals will be provided at no additional charge. The added seals are expected to widen the uses for this fitting which permits joining stainless steel pipe without threading, flaring or welding.

•

Sellers Booster Jet, for use in plants with low pressure steam facilities, makes possible propelling a jet of hot water and detergent for heavy duty cleaning. Using ordinary cold water and plant steam from 5 to 25 psi, the unit converts the 5 psi inlet steam to a 100 psi dis-

(Continued on Page 13)



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3030 W. Pafford P. O. Box 11068 Fort Worth 9, Texas

NEW PRODUCTS

(Continued From Page 12)

charge. Detergents up to 25 percent of total volume and temperatures from 160 to 210 degrees can be used. Manufacturer is Sellers Injector Corp., 1600 Hamilton St., Philadelphia, Pa.

•

Tapecoat Company, 1523 Lyons St., Evanston, Ill. has issued an 8-page brochure, "Where to Use Coal Tar Protection," available on request. The brochure describes and illustrates successful uses of coal tar impregnated wrapping tape in preventing corrosion.

•

Demineralization, Including Silica Removal, by Ion Exchange, a 28-page bulletin of The Permutit Company, 330 West 42nd St., New York 36, N. Y. describes ion exchange principles and equipment, design features, recommendations and specifications.

•

Five free bulletins describing Pittsburgh Coke and Chemical Company's 100-series coal tar base coatings are available from Protective Coatings Division, Pittsburgh Coke & Chemical Company, Room 1953, Grant Bldg., Pittsburgh, Pa.

•

Glidden Company will provide technical assistance for large scale production of titanium dioxide in Japan.

•

Effects of Velocity on Corrosion by Water, by H. R. Copson, an 8-page reprint from Industrial and Engineering Chemistry, Vol. 44, Page 1745, (1952) Aug. is available from International Nickel Co., Inc., Dept. EZ, New York 5, N. Y.

•

Veos Wall Tile, which measures 68 square inches in size and weights 1.15 lb. per sq. ft., manufactured by the Porcelain Enamel Products Corp., Waltham, Mass. is being used in 6000 new houses being erected by Levitt and Sons, Edgely, Pa.

•

Vinylite VMCH resin for Coatings, Technical Release No. 12, of the Bakelite Company, a Division of Union Carbide and Carbon Corp., 300 Madison Ave., New York 17, N. Y. describes the distinctive properties of VMCH resin, which while essentially the same as Resin VYHH, contains about one percent of interpolymerized maleic acid. The carboxyl groups of this acid are credited with the unusual properties of the resin, which include high adhesion to clean metal surfaces and points of reactivity on the resin molecular chains for cross-linking reactions. The 16-page and cover booklet describes the proper use and formulation of the new resin in surface coatings, with emphasis on the points of difference with older resins. Copies are available on request.

•

Adhesive Systems for bonding foamed styrene to metal or other surfaces have been developed by Atlas Mineral Products Co., Mertztown, Pa. under the name Amphesive 801 and Alfane.

•

Hester Battery Manufacturing Co., Nashville, Tenn. is marketing its Gold Metal Battery which includes a cell cap containing a palladium catalyst which recombines escaping hydrogen and oxy-

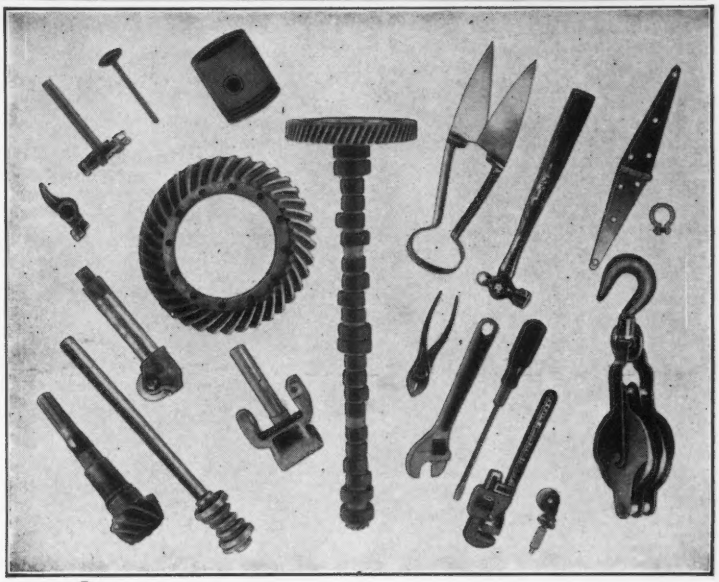
(Continued on Page 14)

AMERICAN CHEMICAL PAINT COMPANY

AMBLER CHEMICALS ACP PROCESS PENNA.

Technical Service Data Sheet

Subject: RUST PROOFING WITH PERMADINE®



Steel parts that have been Permadized and then "sealed" with a rust-preventive oil such as "Granoleum" are effectively protected from rust. And, if the oiled "Permadine" coating should be damaged, rusting will not spread beyond the area of exposure.

Note: Automotive and other rubbing parts subject to friction are usually given "Thermoil-Granodine" manganese-iron phosphate coatings for both wear-resistance and protection from corrosion.

DATA ON THE "PERMADINE" COATING

Type of coating	Zinc phosphate
Object of coating	Rust and corrosion prevention
Typical products treated	Nuts, bolts, screws, hardware items, tools, guns, cartridge clips, fire control instruments, metallic belt links, steel aircraft parts, certain steel projectiles and many other components
Government Specifications	U.S.A. 57-0-2C; Type II, Class B MIL-C-16232, Type II U.S.A. 51-70-1, Finish 22.02, Class B AN-F-20 Navy Aeronautical M-364 JAN-L-548
Scale of production	Large or small volume; large or small work
Method of application	Dip Barrel tumbling, racked or basketed work
Equipment notes	Immersion tanks of suitable capacity. Cleaning and rinsing stages can be of mild steel. Coating stage can be of heavy mild steel or stainless steel.
Chemicals required	"Permadine" No. 1
Pre-cleaning methods	Any common degreasing method can be used. Alkali cleaning ("Ridosol"), Acid cleaning ("Deoxidine"), Emulsion-alkali cleaning ("Ridosol" - "Ridoline"); vapor degreasing, solvent wiping, etc., are examples. Acid cleaning may need to follow other cleaning methods if rust or scale is present.
Bath Temperature	190° - 205°F.
Coating time	20 - 40 minutes
Coating weight range	1000 - 4000 mgs. per sq. ft.
Technical Service Data Sheets	No. 7-20-1-2 T.M. No. 5

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CHEMICALS ACP PROCESSES

CLEANING, COATING, WRAPPING & RECONDITIONING

★

HOT DOPE

Straight from the Kettle on PIPE PROTECTION

★

By Boyd Mayes

● We landed a job the other day that sort of got us thinking. Half dozen joints of used 2″ to be cleaned, coated and wrapped. First, though, we had to straighten the kinks out and bevel the ends. It was pretty much the worse for wear. But it got the same precision workmanship that a hundred miles of big inch would get in our plant. And, we didn't have to bid on this one. It just rolled in. What got us thinking was that some yards that have up "Cleaning — Coating — Wrapping" signs might have thrown this little one back. We've coated, wrapped and reconditioned more than 300 million feet of pipe in our day, and we've never turned down a little trouble job for a customer yet. They're a part of our 25 years of continuous service to the Pipe Line Industry.

MAYES BROS.

1150 McCarty HOUSTON, TEXAS ORchard 7566

NEW PRODUCTS

(Continued From Page 13)

gen from decomposed water into water, thereby returning to the cell most of the water which would escape as gas.

●

Efficient Pickling With Rodine, Bulletin No. 13 of American Chemical Paint Co., Ambler, Pa., an 80-page, 6 x 9 inch, paper bound booklet, describes in detail the uses of Rodine inhibitors in pickling applications. Part V gives a large number of suggested practices for pickling typical products. A series of tables listing typical standard Rodines for use with a number of pickling chemicals is included. The booklet includes a comprehensive index and a large volume of practical data and experimental results pertaining to the uses of these inhibitors. Copies are available on request from the company.

●

Boltaron 6200 polyvinyl chloride threaded IPS pipe fittings (tees, 45-degree and 90-degree elbows and couplings) are being manufactured by H. N. Hartwell & Son, Inc., Box 26, Boston, Mass. Fittings ranging from ¼-inch to 2 inches are stocked and pipe to match is available in 10 and 20-foot lengths.

●

Rustbond Primer, a product of the Carboline Company, 7603 Forsyth Blvd., St. Louis 5, Mo. is designed to be applied over rust, and acts to chemically and mechanically bind steel, rust and primer together. It wets and changes rust, but does not dissolve it in the normal sense, manufacturers say. The material adheres almost perfectly to rusty steel, or rust or sandblasted surfaces. Tests reported by the company indicate: It doesn't adhere to smooth, shiny steel, unless thoroughly aged. It covers rough and sharp edges as heavily as flat surfaces. It is unplasticized and won't burn in ordinary flame. It reduces rust, manifestly to iron but doesn't form water or liberate free oxygen. It ages curiously. After 8 weeks it resists action of all common paint removers, including xylene and methyl ethyl ketone. It possesses good resistance to most acids and after aging to most solvents. It is recommended as a primer coat beneath vinyls and is considered excellent for rubber base, neoprene or other corrosion resisting coatings.

●

G-8 a melamine laminate made by Synthane Corp., Oaks, Pa., is available to manufacturers of electrical and power equipment as an alternate to NEMA Grade 5 glass-base material, whose electrical properties it equals. It is useful also in structures requiring corrosion resistance.

●

Globe Steel Tubes Co., Milwaukee 46, Wis. has issued a 12-page Bulletin 103-Z on its steel and stainless steel tubes and welding fittings. Materials are described and properties listed.

●

Products-Research-Service, Inc., is now located on Main Street, Belle Chasse, La., P. O. Box 6116, New Orleans, La.

●

Spray-Strip, being produced by Eagle Chemical Company, Joliet, Ill. can be applied cold by spray, brush or dip methods, dries in 20 minutes and can be stripped off in a single sheet. Samples are available from the manufacturer on request.

●

Ferrolum lead steel direct fire gas burner immersion heaters for heating corrosive liquids are being made by Knapp Mills, Inc., New York. The lead clad on the outside of the burner pipe does not reach the melting point because the heat is so rapidly dissipated into the liquid.

●

COCOR CR-39, CP-1 and CO-3 as well as CP-2 UHF insulation sheet and rod are featured in a 8-page illustrated bulletin by Cast Optics Corp., 1 Post Road, Riverside, Conn. These optically clear plastic sheets are: CR-39—a thermosetting allyl resin, highly resistant to many chemicals, abrasion and useful for lenses, mirrors and photographic filters; CO-3—an allyl based resin with special craze-resistance; CP-1—a cast polystyrene and Cp-2, with high dielectric strength. A copy of a new catalog, "Cast Optics," is available and the company will consider requests for free samples from potential users.

●

Monsanto Chemical Company's Plastic Division has reorganized its sales department. Industrial resins have been assigned to a newly created section of the sales department headed by Edmond S. Bauer, Jr., of Springfield.

●

Hypro Engineering Inc., 404 North Washington Ave., Minneapolis, Minn. has developed a self-priming pump to handle wettable powder emulsions and emulsified solutions. The case is Ni-resist and the rollers are nylon.

●

Tin-Nickel Alloy, in proportions 65 percent tin, 35 percent nickel approximately, is now being plated on metal, producing a bright, corrosion resistant coating. Because the material is not cathodic to steel, corrosion resistance is in proportion to lack of porosity, or roughly in proportion to thickness. It is moderately ductile, free of internal stress and easy to deposit thickly in crack-free layers. It is suggested for use in almost any application normally finished in nickel plus chromium, and in most cases the single plate takes the place of both the chromium and nickel plating cycles. It can be plated directly on copper, brass and steel, but for best results a copper undercoat should be provided over steel. Much additional information on this new material, first announced by the Tin Research Institute of England, is available in Bulletin Sheet No. 300, October 1952, of Metal and Thermit Corp., Chemical Division, 100 East 42nd St., New York 17, N. Y. Technical assistance with the new material is offered.

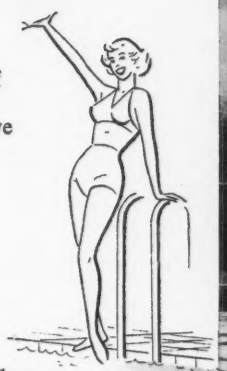
●

Ruberoid Perforated pipe line felt is designed to permit air and gasses trapped in the wrapping operation to escape, improving the continuity of the coating. Enamel extruded into the perforations acts to hold the felt securely in place. Further information and samples can be obtained from S. D. Day Company, 1973 West Gray Ave., Houston 19, Texas.

●

Freedom-Valvoline Oil Co. has opened a new plant for the manufacture of thin film rust preventives at its Freedom, Pa. refinery. The plant formerly was located at Butler, Pa.

For long term, maintenance-free corrosion protection specify Metallizing



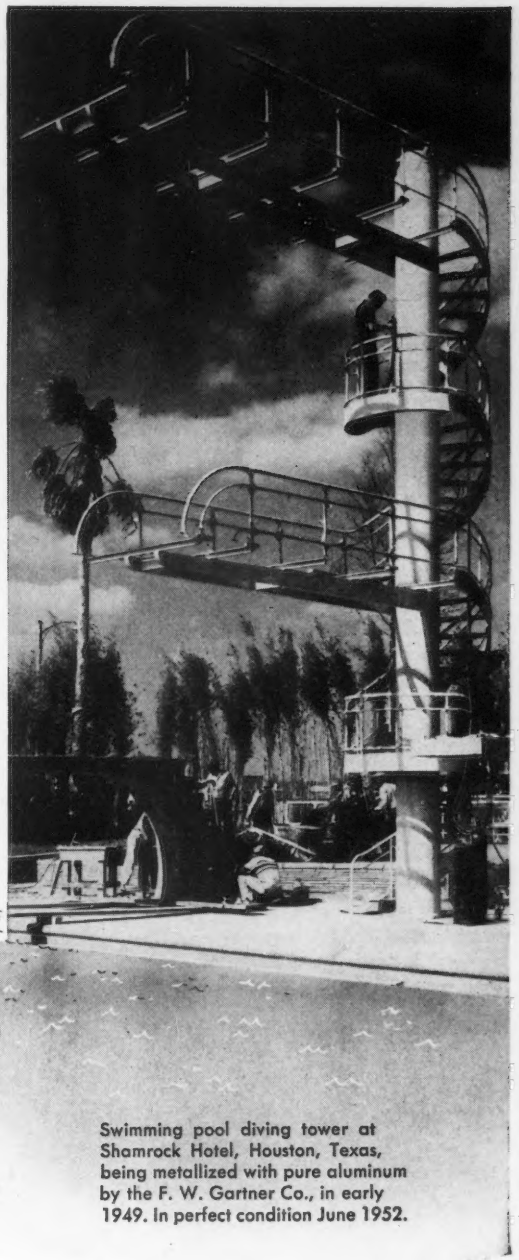
The long-lasting, corrosion resistant qualities of pure metallized zinc and aluminum coatings are well known. Life expectancies for protective coatings of this nature, properly applied, range upwards of 20-30 years without further attention.

The Metco Systems*, a new series of 18 basic engineering specifications developed by Metallizing Engineering Co., Inc., cover the protection of structures and equipment under a wide range of corrosion conditions, including immersion in salt or fresh water of various pH values; exposure to water ballast, condensate and some mild acid solutions, and to salt, humid, rural and industrial atmospheres ranging from light to heavy.

The Metco Systems are the result of over 19 years' experience with pure zinc and aluminum coatings on many different types of structures and equipment. They provide the answer to standardization of surface preparation, coating thickness for various service conditions and after-coatings to meet specific requirements.

The Systems also provide for meeting appearance requirements with specific organic coatings in a range of colors, all thoroughly tested for compatibility with the metallized zinc and aluminum.

The following organizations are set up to provide positive corrosion protection at lower annual cost in accordance with Metco System specifications. For further information, or a copy of descriptive bulletin, contact the one nearest you.

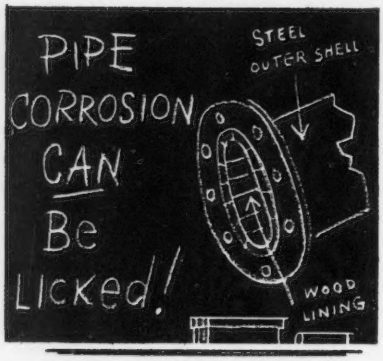


Swimming pool diving tower at Shamrock Hotel, Houston, Texas, being metallized with pure aluminum by the F. W. Gartner Co., in early 1949. In perfect condition June 1952.

*Reg. U.S. Pat. Off.—Property of Metallizing Engineering Co., Inc.

Metco System contractors

Baltimore 30, Maryland **THE SOUTHERN GALVANIZING COMPANY** 1618 Bush Street Tel. Gilmor 7711	**New Orleans 13, Louisiana** **GULF ENGINEERING CO., INC.** 1000 South Peters Street Tel. Canal 4421	**Newport Beach, California** **CLARK METALLIZING, INC.** 506 – 30th Street Tel. Harbor 2509	**Barberton, Ohio** **AKRON SAND BLAST CO.** 50 E. Springfield Rd. Tel. Plaza 3412	**Buffalo 1, N. Y.** **METAL-CLADDING, INC.** Lakeview & Porter Avenues Tel. Elmwood 9536
Lincoln Pk. 25 (Detroit), Mich. **DIX ENGINEERING CO., INC.** 1417 Dix Road Tel. Dunkirk 1-8822	**Philadelphia 29, Pa.** **MW PROTECTIVE COATINGS DIV. OF METALWELD, INC.** Scotts Lane & Abbottsford Ave. Tel. Victor 8-1810	**Chicago 8, Illinois** **CHICAGO METALLIZING CO., INC.** 2606 West 16th Street Tel. Rockwell 2-2600	**St. Louis 10, Missouri** **ST. LOUIS METALLIZING COMPANY** 625 South Sarah Street Tel. Newstead 5253	**Houston, Texas** **F. W. GARTNER CO.** 3805 Lamar Avenue Tel. Atwood 5338	**Brooklyn, N. Y.** **ARTHUR TICKLE ENGINEERING WORKS, INC.** 21 Delevan Street Tel. Main 5-4200



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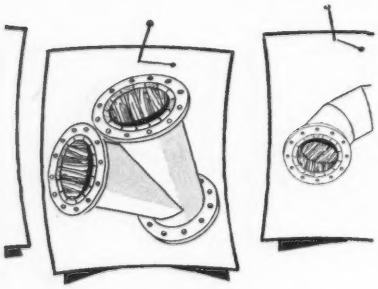
For service up to 180° F. and 250 p.s.i. Higher pressure ratings for special service requirements. All pipe flanged and available in 10' and 20' standard lengths or "tailor-made" to your specifications. Easy to cut and reflange. All flanges have standard ASME bolt circle.



Woodlined fittings are available in standard and special designs for all diameters. For catalog and additional information write Dept. C.

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PERSONALS

Robert A. VanIderstine has been elected assistant secretary of the Pfaudler Company, 1000 West Avenue, Rochester, N. Y. He also has been transferred from the company's sales department to its general management staff as engineering coordinator, in which capacity he will be chairman of the Interplant Engineering Committee. He will act also as secretary of the executive and products committees.

•

K. O. Schlentner, assistant manager—research has been named manager-heating research of the National Radiator Company, Johnstown, Pa.

•

C. G. Munger has been elected vice-president of Amercoat Corporation, South Gate, Cal.

•

Paul W. Atwood has been elected president and **Roland D. Earle,** director of new product development of Union Bay State Chemical Company, 491 Main St., Cambridge, Mass.

•

Harold L. Danziger, formerly assistant sales manager of the R. M. Hollingshead Corp. Automotive Private Brand Division has been appointed manager of all private brand sales.

•

Walter E. Palmer of Cresskill, N. J. has been named salesmanager of All-State Welding Alloys Co., Inc., White Plains, N. Y.

•

Harold D. Newell has been named consulting metallurgist and **John J. B. Rutherford** chief metallurgist of the Tubular Products Division of the Babcock and Wilcox Company, Beaver Falls, Pa. Mr. Newell, who has been with the company since 1919 will be relieved of detail work in connection with supervision of the research section of the laboratory. Mr. Rutherford will be in charge of the laboratory's research section, process and product development and customer metallurgical service.

•

Robert F. Carr, Jr. has been elected vice-president of the Dearborn Chemical Company, Merchandise Mart Plaza, Chicago.

•

Charles E. Wilson, formerly president of General Electric Company has been presented with honorary membership in the American Society of Tool Engineers.

•

Kendall B. Rowell, 52, chief engineer of the American Locomotive Company died December 12 following an illness and operation. He was named Alco chief engineer last November 5.

•

Harry R. Condon, vice-president and general manager of Koppers Co., Inc. wood preserving division, retired November 30 after 25 years with Koppers or companies which since have been absorbed by Koppers. **Walter P. Arnold** has been named to succeed him.

•

Recent appointments by Atlas Mineral Products Co., Mertztown, Pa. include: **Kenneth Snyder,** Western Division regional salesmanager; **Edison C. Sickman,** New York District salesmanager; **Earl A. Erich,** assistant salesmanager fabricated products, **Donald Deakin,** assistant salesmanager water and sewer materials; **Frank Pegg,** promoted to sales engineer, Mertztown office; **Donald Weidner,** sales engineer Northeastern Pennsylvania; **John Pritchett,** sales engineer Chicago territory; **John R. South,** sales engineer Cincinnati territory; **Frank Beauchner,** purchasing agent; **Jim Fry,** in charge of new products development; **Martin H. Smith,** assigned to corrosion problems in the paper and textile industries and **Robert E. Evans,** promoted to plant manager, Texas.

•

Arthur Murphy has been appointed field engineer by Richardson-Allen Corp., Flushing, N. Y. for the New England area to service selenium rectifier installations.

•

John L. Bray, 52, professor of metallurgy at Purdue University since 1923 and head of the school of chemical and metallurgical engineering from 1935 to 1947 died December 6.

•

Ernest A. Schoefer, formerly executive secretary of the Alloy Casting Institute has been named executive vice-president of the association.

•

W. J. Hegerty has been appointed sales manager of the Chemical and Process Equipment Division of Colonial Iron Works Company, Cleveland, Ohio. For the past five years he has been manager of the firm's New York office.

•

George W. Mikkelsen has been named director of the marine chemical department of Fine Organics, Inc., 211 East 19th St., New York 3, N. Y.

•

J. D. Young has been promoted to field sales manager and **W. F. Rye** to sales service manager of Tuthill Pump Company, Chicago.

•

Richard L. Hoff has been appointed development metallurgist by Superior Tube Company, Norristown, Pa. **Harry W. Poole** was named quality control director by the company.

•

Joseph Becker, noted designer of chemical-recovery coke ovens, retired December 31 as vice-president and general manager, Engineering and Construction Division of Koppers Company, Inc. He will remain as consultant to Koppers and to the steel industry.

•

William F. Roeser, consultant for the Building Technology Division of the National Bureau of Standards has been given the Sigma Tau gold medal for meritorious service.

•

Gordon Russell has been appointed distribution engineer by Union Gas Company of Canada, Ltd. He will continue to direct temporarily the anti-corrosion program of the company which he has supervised.

•

Frank Hazzard, district sales engineer for the Haveg Corporation's Southeastern territory died recently. John M. Ward, transferred from the company's Marshallton, Del. plant has taken his place at the Southeastern offices located at Atlanta, Ga.

Vol. 9

Corrosion Abstracts

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NATIONAL ASSOCIATION of CORROSION ENGINEERS

1061 M & M Bldg. Houston, Texas

1. GENERAL

1.1 Miscellaneous

1.1, 1.7.1, 1.2.6

Corrosion Control by Magic—It's Wonderful. H. H. Uhlig. Corrosion Laboratory, Department of Metallurgy Massachusetts Institute of Technology, Cambridge, Mass. *Corrosion*, **8**, No. 10, 361-364 (1952) Oct.

The author, citing an historic case of self-delusion and another instance of an outright attempt at fraud in the promotion of claims to scientific discoveries, suggests that lack of rapid evaluation technique and defective education in engineering are responsible in part for the ease with which bogus "dopes" and processes are sold. While urging that new ideas not be discounted in advance it is urgent that claims for new ideas and devices be checked by known scientific methods before acceptance.

The following guides are suggested for evaluating new schemes for controlling corrosion: 1) If claims are based on testimonials and not on available authoritative data, dismiss the device until authoritative evidence is supplied. 2) Be cautious concerning devices claims for which include statements obviously wrong. 3) Be cautious of devices operated by no known scientific principles.

The National Association of Corrosion Engineers is advised to set up a council of respected members of the corrosion engineering profession to pass on acceptable advertising in Corrosion and acceptable exhibits at its national conferences.

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AER—Aeronautical Engineering Review, Institute of Aeronautical Sciences, Inc. 2 East 64th St., New York 21, N. Y.

ALL—The Abstract Bulletin, Aluminum Laboratories, Ltd. P. O. Box 84, Kingston, Onatrio, Canada.

AWWA—Journal, American Water Works Association. Amer. Water Works Assoc., 521 Fifth Ave., New York 17, N. Y.

BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

BTR—Battelle Technical Review, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio.

BNF—Bulletin; British Non-Ferrous Metals Research Association. 81-91 Euston St., London NW 1, England.

CALCO—Calco Chemical Division, American Cyanamid Corp. Bound Brook, New Jersey.

CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

CEC—Consolidated Edison Co. of New York, Inc. 4 Irving Place, New York 3, New York.

EL—Electroplating. 83/85 Udney Park Road, Teddington, Middlesex, England.

EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

GPC—General Petroleum Corp. of California. 2525 East 37th St., Los Angeles 11, Calif.

INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.

IP—Institute of Petroleum. 26 Portland Place, London W#1, England.

JSPS—Japan Society for the Promotion of Science, Address: Mr. Hayata Shigeno, Secretary, Committee of Preventing Corrosion, c/o Government Chemical Industrial Research Institute, 1-Chome Nakameguro, Meguro-ku, Tokyo, Japan.

MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.

MI—Metallurgia Italiana. Associazone Italiana di Metallurgia. Via S. Paola, 10, Milano, Italia.

MR—Metals Review, American Society of Metals. 7301 Euclid Ave., Cleveland 3, Ohio.

NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.

NBS—National Bureau of Standards. Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.

NSA—Nuclear Science Abstracts. United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tenn.

PDA—Prevention Deterioration Abstracts. National Research Council, 2101 Constitution Ave., Washington 25, D. C.

RA—Refrigeration Abstracts, American Society of Refrigeration Engineers. 40 West 40th St., New York 18, N. Y.

RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.

SE—Stahl Und Eisen, Verlag Stahleisen, M. B. H., Dusseldorf, August-Thyssen Str. 1. Postscheck Koln 4110, (22a) Dusseldorf, Germany.

TIME—Transactions of Institute of Marine Engineers. 85 The Minories, London EC 3, England.

UOP—Universal Oil Products. 310 South Michigan Ave., Chicago, Illinois.

ZDA—Zinc Development Association. Lincoln House, Turl Street, Oxford, England.

1.3 Reviews

1.3, 5.6.3

Protecting Machined Parts from Corrosion. *Mech. World Eng. Record,* 1951, 49, Jan. 19; *Product Eng.,* **22,** No. 6, 243-244 (1951) June.

A review is given of corrosion preventatives, including soft- and hard-film materials, oil, hot-dip and strippable coatings, the causes of failure and the choice of protectives.—INCO.

1.3, 8.8.5, 8.8.3

Advances in Productive Methods in Metal Finishing. ADOLPH BREGMAN. *Metal Progress,* **59,** 76-81 (1951) Jan.

Describes recent advances in the metal finishing industry with regard to metal cleaning, mechanical finishing, electroplating, electroforming, hot galvanizing, non-metallic finishing, shortage of materials and waste disposal.

1.5 Directories of Material

1.5, 6.1

Corrosion-Resistant Materials for Marine Service. L. W. JOHNSON AND E. J. BRADBURY. *Trans. Inst. Marine Eng.,* **63,** No. 4, 59-80 (1951) April.

Theoretical aspects of corrosion (forms and phenomena); corrosive media encountered in marine engineering (fuels and combusion products; boiler water and steam; sea-water; the atmosphere); corrosion behavior, mechanical and physical properties of various metallic materials, including copper and its alloys, nickel alloys, aluminum alloys, ferrous materials and metallic coatings. 42 references.—BNF.

1.7 Organized Studies

1.7.1, 3.5.9, 3.7.4

Report of Joint Committee on Effect of Temperature on the Properties of Metals. ERNEST L. ROBINSON, chairman. American Society for Testing Materials, Preprint 92, 1951, 7 pages. (GA401 Am35p.)

Summarizes meetings, publications, technical papers, finances, research projects, personnel and panel activities.—BLR.

1.7.1, 5.1

Protective Coatings Research by the Bureau of Ships. *Paint and Varnish Production,* **41,** 13-16, 26 (1951) Apr.

Presents descriptive survey of various problems being studied. Includes means for prevention of corrosion, deterioration, wear and fouling. Methods include the application of electrochemical principles; coatings such as paints and organic preservatives in liquid form; metallic ceramic coatings.—BLR.

1.7.1, 5.4.1, 5.3.1

The Work of the Protective Coatings (Corrosion) Sub-Committee.* F. FANCUTT AND J. C. HUDSON. *Corrosion,* 8, No. 11, 366-374 (1952) Nov.

The authors survey the result of investigations of protective coatings for structural iron and steel extending over twenty years. In the field of painting, the research has thrown into relief the vital importance of current surface preparation and the value of using inhibitive priming paints. Studies of the formulation of anti-corrosive paints, both for land and marine structures are in progress in collaboration with the paint industry. In the field of metallic coatings, basic data have been obtained for the performance of aluminum, cadmium, lead, tin and zinc coatings under various conditions of atmospheric exposure. The durability of zinc coatings has been shown to be roughly proportional to their thickness and but little affected by the process of application. Sprayed aluminum has proved an effective coating but lead coatings have given good results only in an industrial atmosphere, where they become covered with a protective sulfate film.

*Read before Liverpool Section of the Oil and Color Chemists' Association, London. February 8, 1952. Authors are indebted to the association for permission to reproduce it here. Presented by A. J. Liebman, Dravo Corp., Pittsburgh, at the Eighth Annual Conference, National Association of Corrosion Engineers, Galveston, Texas, March 10-14, 1952, under the title "Values of Surface Preparation and/or Pretreatment for Use in Conjunction with Various Outstanding Paint Systems in Industrial and Marine Atmospheres."

1.7.2, 2.2.7

Corrosion Testing at Sea Horse Institute. W. A. RAYMOND. *Org. Finishing,* **12,** 9-11, 23 (1951) Feb.

Facilities at new site which replaces the Kure Beach site, formerly used by International Nickel Co. for marine corrosion and fouling tests.—MR.

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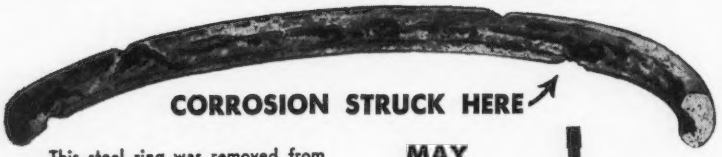

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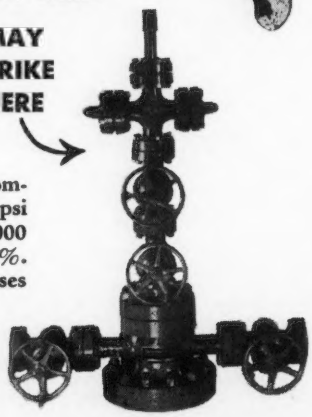

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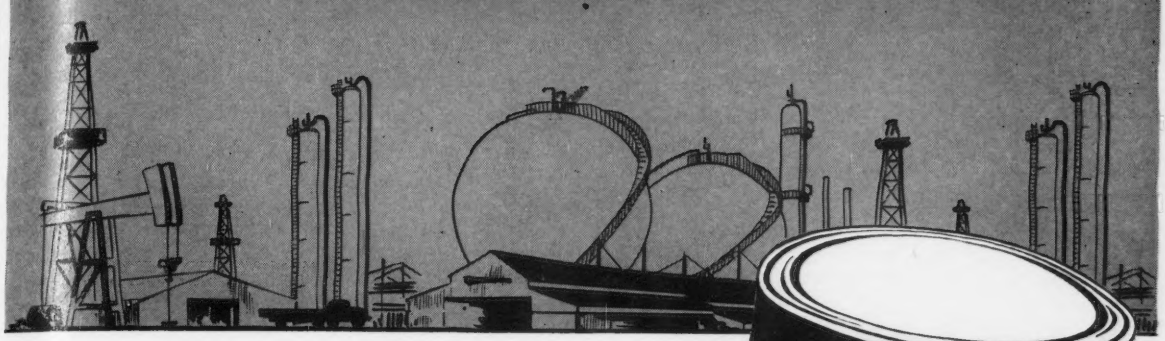

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2. TESTING

2.2 On Location Tests

2.2.1, 2.3.1

Corrosion Tests and Service Performance. F. L. LaQue. American Society for Metals, "Interpretation of Tests and Correlation With Service," 1951, p. 141-192. (TA 460 Am35i.)

Discusses relationship of the above. Laboratory and field-test procedures are described and illustrated. Effects of various factors are discussed. Typical results are charted, tabulated, and discussed. Conclusions are summarized. 39 ref.—BLR.

2.2.7, 2.2.2, 6.4.2, 5.3.2, 4.6.11

Exposure Tests of Galvanized-Steel-Stitched Aluminum Alloys. Fred M. Reinhart. National Advisory Committee for Aeronautics, Technical Note 2299, Feb. 1951, 23 pages.

Sheets of 24S-T3 and Alclad 24S-T3 joined to themselves by stitching with galvanized high-carbon steel wire were exposed in a marine atmosphere and in the tidewater to determine service life. Both alloys are satisfactory with respect to corrosion resistance for service in marine atmospheres. The Alclad 24S-T3 alloy is satisfactory for short periods of time, where installation is subject to frequent wetting by sea water. The use of 24S-T3 sheet is not satisfactory when subject to wetting by sea water. Includes micrographs of results.

2.3 Laboratory Methods

2.3.2, 5.4.5, 1.7.1

N.B.S. Laboratory for More Accurate Accelerated Paint Tests. *Paint, Oil Chem. Rev.*, **114,** No. 5, 17 (1951).

A description is given of a machine for research into the accelerated weathering of paints at the National Bureau of Standards. Painted panels are mounted peripherally on the interior of a horizontal aluminum drum, 31 inches in diameter, rotating about its vertical axis, and subjected to light from a carbon arc running at 130-145 volts and 15-17 amps. Deionized water, pH 6.2, can be sprayed on to the panels for any desired period. Ambient temperature is maintained at 29± 4° by blowing a controlled mixture of heated and cold air through the machine.—RPI.

2.3.7, 2.4.2

New Layer Thickness Meter. *Practical Engr.*, **23,** No. 579, 364 (1951) Apr. 20.

The pocket-sized instrument employs a permanent magnet and can be used to measure the thickness of non-magnetic coatings on steel bases or of non-magnetic foils, etc. if they are placed on a steel surface. The meters are available in three forms, to measure thicknesses up to 0.005, 0.010 and 0.030 inches.—ZDA.

2.3.9, 6.3.4

Radioisotopes Aid Studies of High-Temperature Materials. W. E. Jones. *Steel*, **128,** No. 13, 78 (1951).

The use of a radioactive wolfram isotope for the study of the structure of a cobalt-base alloy is described. Health precautions are discussed.—MA.

2.4 Instrumentation

2.4.2, 2.4.3

Taking Corrosion Measurements. F. Ringer. *Petroleum Engr.*, **23,** No. 5, D115-116, 118-120 (1951) May.

The Susquehanna electrolysis meter and vacuum tube voltmeter, useful as field instruments in corrosion investigation on buried pipe, cable and other structure are described in detail.

2.4.2, 2.4.3

Thickness Gauge. *Rev. Sci. Instruments*, **22,** No. 4, 286 (1951).

A description of the Gardner gauge, a penetration-type electrically-indicating micrometer gauge.—RPI.

2.4.3

Inspection by Radon of Large High-Pressure Vessels. V. E. Pullin. *Engineer*, **189,** 262-263 (1950) Mar. 3.

Probably the first example of the use of high concentrations of radon for routine examination of Grade I pressure vessel welding.—MR.

2.4.3

Nondestructive Testing of Defective Bimetallic Joints and of Laps in Thin Sheet Metals. (In Dutch.) J. Van Nieuwkoop. *Metalen*, **6,** 110-112 (1951) Apr. 15.

Describes apparatus, especially designed for nondestructive examination of sheet metals for discontinuities and of thin parts for defects in joints. Deals with possibilities and limitations of the apparatus.—BLR.

2.4.3, 2.4.2

New Instruments for Magnetic Nondestructive Testing. (In German.) Werner Jellinghaus. *Archiv fur das Eisenhuttenwesen*, **22,** 111-115 (1951) Mar.-Apr.

Describes design and operation of three German instruments. Includes diagrams and graphs.—BLK.

2.5 Specifications and Standardization

2.5, 5.3.4, 1.7.1

Report of Committee B-8 on Electrodeposited Metallic Coatings. C. H. Sample, chairman. American Society for Testing Materials, Preprint 13, 1951, 27 pages. (TA401 Am35p.)

Includes recommendations affecting standards for the above and proposed tentative recommended practices for preparation of zinc-base die castings for plating, for preparation of and plating of aluminum alloys and for preparation of and plating of stainless steels.—BLR.

3. CHARACTERISTIC CORROSION PHENOMENA

3.2 Forms

3.2.2

Mechanism of Corrosion Fatigue. (In Russian.) G. V. Karpenko. *Doklady Akademii Nauk SSSR* (Reports of the Academy of Sciences of the USSR), new ser., **77,** 827-830 (1951) Apr. 11.

Results of experimental investigation of the above indicate that two processes are involved: first, formation of fatigue microfissures by adsorption of a corrosive agent during cyclic loading; and

second, the corrosion process itself inside cracks already formed, thus promoting their growth. Results obtained with steel are charted and illustrated.—BLR.

3.2.2, 2.3.5, 6.2.1

Hydrogen Embrittlement Tests on Various Steels. F. A. PRANGE. A paper presented at the Eighth Annual Conference, National Association of Corrosion Engineers, Galveston, Texas, March 10-14, 1952. *Corrosion*, **8**, No. 10, 355-360 (1952) Oct.

Cathodic embrittlement tests were made on a number of alloys having good properties for use in deep corrosive wells. The tests suggest that the maximum hardness for use in embrittling environments should be Rockwell C-20.

3.3 Biological Effects

3.3.4, 7.7, 2.3.3

Effect of Fungus Growth on the Tensile Strength of Pressure-Sensitive Electrical Insulating Tapes. SIGMUND BERK AND LEONARD TEITELL. Frankfort Arsenal Report R-966, 1950, 23 pp. *ASTM Bull.*, 67-71 (1951) May.

Twenty-three of above tapes were tested for fungus resistance using a mixed spore suspension of five species of fungi. The cellulose acetate, vinyl, and polyethylene tapes supported no more than slight mold growth, the glass fabric tapes supported no growth to heavy growth, while paper and cloth tapes were very susceptible to mold attack. Results of breaking strength losses after exposure to mold are given. A yellow flat-stock paper tape was treated with four fungicides and tested for fungus resistance. Good protection against mold growth was afforded by 0.84 percent phenyl mercuric saccharinate. 12 references.—BLR.

3.3.4, 5.4.5

Pullularia as a Cause of Deterioration of Paint and Plastic Surfaces in South Florida. E. S. REYNOLDS. *Mycologia*, **42**, 432-448 (1950).

Illustrations are given of the widespread nature of attack by Pullularia in South Florida on painted test panels, whether fungicidally treated or not and on glass cloth coated with polyvinyl chloride/acetate.—RPI.

3.4 Chemical Effects

3.4.2, 3.8.4

The Catalytic Decomposition of Hydrogen Peroxide by Iron Salts in Acid Solution. J. H. POMEROY, P. F. GRIEGER, AND J. W. GATES, JR., Tennessee Eastman Corp. Sept. 15, 1945. Decl. May 23, 1951. 97 p. (AECD-3162; C-1.375.5).

A theoretical discussion of the catalytic decomposition of H_2O_2 by Fe salts precedes the experimental part. Decomposition rates of H_2O_2 in solutions containing varied concentrations of a number of ions are tabulated. A detailed interpretation of how the results of the catalytic experiments were used to find the laws of catalysis and the various significant equilibrium constants is given. The decomposition of H_2O_2 in acid solutions (pH 0.5 to 3.0) at 25° C follows quite closely the first-order reaction equation $(H_2O_2)_t = (H_2O_2)_0 \exp(-k't)$, where $(H_2O_2)_t$ is the molar concentration of peroxide at time t measured in sec-

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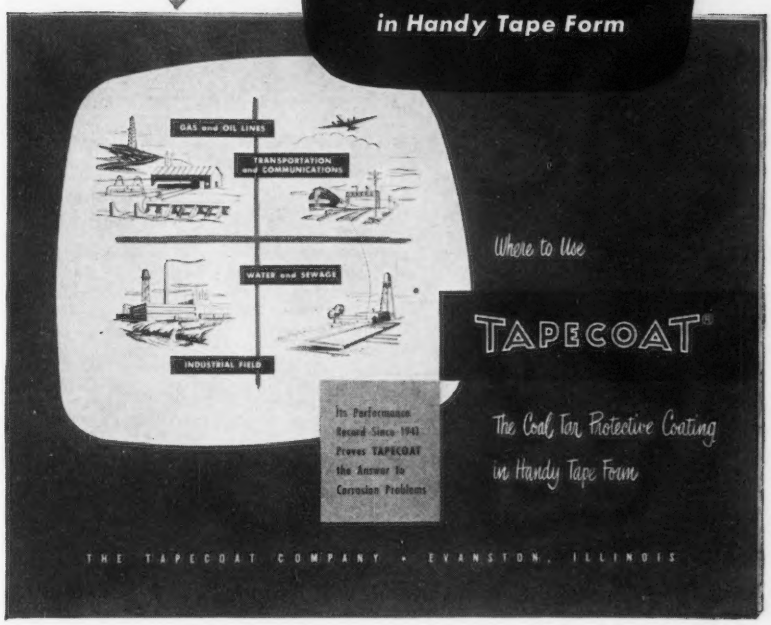
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onds, and $(H_2O_2)_0$ is the initial concentration of peroxide. The constant k′ is defined by $k' = [(21.4 \times 10^{-4})\ (Fe^{+3})]/(H^+)$, where (Fe^{+3}) = the concentration of the ferric ion, and not the concentration of added ferric salt. The active concentration of the ferric ion (Fe^{+3}) in the presence of other substances with which it interacts to form catalytically inactive complex irons, such as water, chloride ion, fluoride ion, sulfate ion, malonic acid, etc., may be calculated by means of several equations which have been derived from a theory of association. The agreement of experimental results with reaction rates predicted from the equations mentioned above is generally satisfactory. The theory most consistent with experimental observations states that the decomposition proceeds by the formation of free radical chain reactions. A tabulation has been made of the chemical reactions and the physical properties of H_2O_2 and its aqueous solutions.—NSA.

3.4.6, 3.8.4

Oxidation Kinetics of Nickel and Cobalt. WALTER J. MOORE AND JAMES K. LEE. *J. Chem. Physics,* **19,** No. 2, 255 (1951).

A letter. Rate constants derived from a study of the kinetics of oxide-film formation on nickel and cobalt foils at oxygen pressure of 10 cm. mercury and temperatures of 400°-900° and 500°-800° C, respectively, are presented and discussed. The rate for cobalt is ~ 25 times that for nickel, but as the activation energies are nearly the same the difference in rates is attributed to pre-exponential or "entropy" factors.—MA.

3.5 Physical and Mechanical Effects

3.5.3, 2.3.9

An Investigation of Surface Damage, Using Radioactive Metals. E. RABINOWICZ. Physics of Lubrication, *Brit. J. Appl. Physics,* Suppl. No. 1, **1951,** 82-85.

In industrial practice, it is generally more important to reduce wear than to reduce friction. Radioactive hemispherical sliders of copper, cadmium, zinc, platinum, silver and stainless steel were slid over a bottom plate and the transfer of activity to the latter recorded by placing it in contact with a photographic plate which blackened locally owing to the radioactive material torn from the hemisphere during sliding. This method will detect down to 10^{-12} g in favorable cases. Metal transfer occurs in the form of discrete fragments and well-lubricated surfaces reduce the transfer, compared with clean surfaces in the ratio 400 or more to 1. On heating well-lubricated surfaces, the coefficient of friction and metal transfer increases markedly at the melting point of the surface film. Metal transfer, in contrast to friction is sensitive to temperature change below the surface film's melting point. 7 references.

3.5.3, 5.8.3, 2.3.9

A Study of Boundary Lubricant Films by Electron Diffraction. J. W. MENTER. Physics of Lubrication, *Brit. J. Applied Physics,* Suppl. No. 1, **1951,** 52-54.

The structures and orientations of long-chain hydrocarbon compounds, including fatty acids and metallic soaps on polished surfaces of platinum, silver, copper, zinc, cadmium, mild steel and nickel were studied by electron diffraction. It is shown that the first monolayer is oriented with the hydrocarbon chains approximately normal to the surface; material above the first monolayer shows a different orientation and structure. Structure and orientation of the monolayer are unaffected by rubbing except in one case, viz. octacosanoic acid. The diffraction patterns remain unchanged over a considerable rise of temperature, but at a critical temperature characteristic of the surface films and the chemical nature of the surface, the diffraction patterns change until ultimately reversible two dimensional melting of the film occurs. Good boundary lubrication requires a closely packed solid film of oriented molecules on the metal surface. 16 ref.—MA.

3.5.3, 5.8.3

The Adsorption of Lubricant Films: A Study of Radio-Active Tracers. A. C. MOORE. Physics of Lubrication, *Brit. J. Applied Physics,* Suppl. No. 1, **1951,** 54-57.

The chemical reaction between radioactive metal foils (platinum, gold, zinc, cadmium and copper), and adsorbed monolayers of stearic acid, ethyl stearate, and octadecyl alcohol, was studied. It is directly verified that when reaction occurs the system shows good lubricating properties at temperatures above the bulk m.p. of the lubricant and up to the softening point of the soap. If no reaction takes place, lubrication occurs only below the bulk m.p. of the lubricant. Reaction does not cease with the formation of a monolayer of soap on the metal; if sufficient materials are present, thick films of soap are built up. The weight of metal detected in the tests is of the order 10^{-7} g/cm² of true surface area. The results obtained by the use of radioactive tracers agree with those obtained by electron-diffraction methods. 16 references.—MA.

3.5.9

Protection of Refractory Metals. *Metal Progress,* **59,** 288, 290 (1951) Feb. Translated and condensed from "Surface Protection of High-Melting Metals to Increase Their Sealing Resistance at High Temperatures," HELMUT BUCKLE, *Metallforschung,* v. 1, Sept. 1946, p. 81-86.—BLR.

3.5.9, 9.1.3

High-Temperature and Scale-Resistant Sintered Materials. (In German.) RICHARD KIEFFER AND FRIEDRICH BENESOVSKY. *Z. Metallkunde,* **42,** No. 4, 97-106 (1951) Apr.

Comprehensive review of literature shows that powder metallurgy is an increasingly used method of producing high-temperature-resistant metallic, semimetallic and nonmetallic materials and castings. Tabulated and graphed data illustrate advances achieved in the field of high-temperature materials. 85 ref.—BLR.

3.6 Electrochemical Effects

3.6.5, 4.3.6

A Study of Several Physical Properties of Electrolytes Over the Temperature Range of 25° C to —73° C. A. B. GARRETT AND SAMUEL A. WOODRUFF. *J. Phys. & Colloid Chem.,* **55,** 477-490 (1951) Apr.

Presents data on the density, viscosity, electrical conductivity and freezing point of several solvent-electrolyte systems over the above range. Such data are of specific interest in study of electrolytes and especially in study of the dissolution of metals over this temperature range.—BLR.

3.6.5, 6.3.11

The Tarnishing of Silver in Aqueous Solutions and Properties of the Layers of Tarnish. (In German.) WALTER JAENICKE. *Z. Elektrochem.,* **55,** 186-193 (1951) Apr.

Describes and diagrams apparatus and procedure for determining the effects of bromine, iodine and sulfur solutions on silver. Overvoltage of the corroding silver electrode was measured against a noncorroding silver electrode. Graphs and tables indicate effects of time, temperature and concentration of the solution on corrosion. Conductivity and mechanism of conductivity of the layer of tarnish was also studied. 25 references —BLR.

3.6.5, 6.4.2

The Electrochemical Behaviour of Aluminum. J. V. PETROCELLI. *J. Electrochem. Soc.,* **98,** No. 5, 183-186 (1951) May.

A study has been made of the reactivity of pure aluminum with iron sulfate in solutions of varying acid strength. Electrode potentials, weight loss data and polarization curves are presented and it is shown that the reaction may be interpreted from an electrochemical point of view. The analysis of the behavior is based on the previously developed theory of the "mixed potential" (Author's summary).—ALL.

3.6.8

Overvoltage at Oxidation-Reduction Electrodes. J. V. PETROCELLI AND A. A. PAOLUCCI. *J. Electrochem. Soc.,* **98,** 291-295 (1951) July.

An experimental study was made of polarization characteristics of the following oxidation-reduction electrode systems: iron sulfate, iron chloride, potassium ferrocyanide-ferricyanide and cerium sulfate. Data are presented which strongly indicate that overvoltage includes an activation overvoltage in addition to that due to concentration polarization. The data are analyzed from the point of view of rate processes.—BLR.

3.6.8, 3.8.4

The Kinetics of Oxidation-Reduction Electrode Reactions. J. V. PETROCELLI. *J. Electrochem. Soc.,* 98, 187-192 (1951) May.

Shows that electrode reactions may be treated as rate processes. A general expression for electrode potential-current density relationship is derived, showing how polarization curves may behave under conditions where concentration overvoltage and activation overvoltage are involved. Suggests that use of this equation may allow such factors as "exchange current" and "transfer coefficients" to be evaluated. 23 references.—BLR.

3.7 Metallurgical Effects

3.7.2, 6.3.6, 6.3.8

Effect of Sulphur and Iron on Copper-Lead Alloys. (In German.) A. RUHENBECK. *Giesserei,* **38,** No. 5, 103-106 (1951) Mar. 8.

In an examination of the effect of sulfur on structure and hardness of copper-lead (lead bronze) it is found that sulfur in the ratio of lead : sulfur 100 : 1 has most favorable effect on subdivision of lead. Addition of iron beyond solubility limit in copper gives rise, in view of high sur-

face tension of iron, to a globular and particularly fine-grained structure of copper-lead. This "globular" material has higher strength and better gliding properties than usual. Effect of chromium and nickel is briefly mentioned. Sulfur has no effect on solubility limit of lead in copper, being present as lead-sulfur. —BNF.

3.7.4, 6.4.2, 2.3.9, 2.3.6

Aluminum—7% Magnesium Solid Solution. (In French.) PIERRE A. JACQUET. *Compt. rend.*, **233**, 621-623 (1951) Sept. 10.

Electron microscope studies show morphologic differences between the phases which separate on the grain surfaces from an aluminum-7% magnesium solid solution on annealing at 160 and 250° C. Only the 160° C treatment sensitizes the alloy to intergranular corrosion. The corrosion (anodic in sodium chloride solution) does not seem to attack the separating component itself but rather the surrounding matrix. The phase formed at 250° C is corroded integrally with the grains. 6 figures.—NSA.

3.8 Miscellaneous Principles

3.8.2

The Potential of the Iron Electrode. (In German.) J. D'ANS AND W. BRACKHEIMER. *Naturwissenschaften*, **38**, 282 (1951) June 2.

Brief report of experimental results indicate that they influence current concepts of iron corrosion. Includes diagrams.—BLR.

3.8.4

The Graphical Representation of Metallurgical Equilibria. C. J. OSBORN. *Journal of Metals; Trans. Amer. Inst. Mining and Met. Eng.*, **188**, 600-607 (1950) March.

Graphs for temperature dependence of free energies of formation of metallurgically important oxides, sulfides, chlorides, carbonates and sulfates, which simplify derivation of metallurgical information. 70 ref.—MR.

3.8.4, 2.1.1

The Five Properties Concerned in the Transport of the Active Corrodant Agent. R. C. L. BOSWORTH. *J. Proc. Royal Soc. New South Wales*, **84**, No. 1, 53-58 (1950).

Corrosion processes are described in terms of maximum corrosion rate q_o, conductnace term j, compliance term K, internal term ξ, and electrochemical driving force E, determination of which have been described in earlier papers by the author. (*ibid.*, 1949, **83**, 8, 17, 25, 31). For copper in acetic acid, K is shown to be dependent on the solubility of the corrodant for oxygen. Rate of corrosion of specimens immediately after immersion in the corrodant may show transient phenomena. Where the effect of ξ may be neglected, the time constant for such transients is roughly $\propto$ the sq. of the depth of immersion.—MA.

3.8.4, 3.4.6

Kinetics of the Formation of Oxide Films on Zinc Foil. WALTER J. MOORE AND JAMES K. LEE. *Trans. Faraday Soc.*, **47**, No. 5, 501-508 (1951) May.

Oxidation kinetics of zinc foil were studied at temperatures from 300° to 400° C and pressures of 1.0-40.0 cm of mercury. Below 350° C the rate follows a

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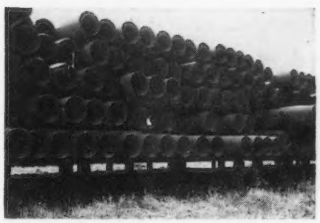

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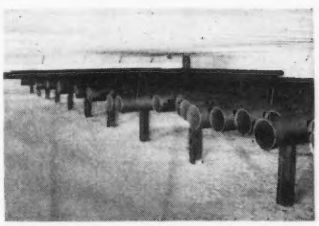

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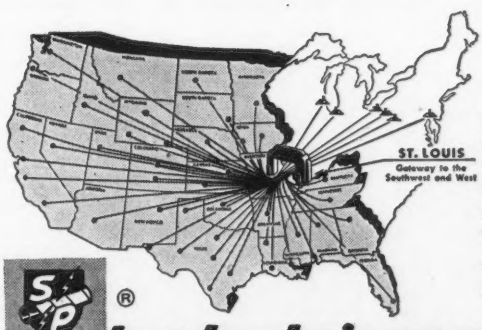
Standard Procedures were created to adhere strictly to the requirements of quantities and methods of the coating manufacturers, so as to secure the very best results.



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logarithmic equation. Above 370° C it follows a parabolic equation. Parabolic rate constant is markedly pressure dependent. This behavior can be interpreted in terms of activated adsorption of oxygen at the zinc-oxide surface. 14 references.—BLR.

3.8.4, 3.4.6

The National Physical Laboratory: Fundamental Metallurgical Research in Progress. N. P. ALLEN. *Metallurgia,* **42,** No. 251, 186-187 (1950).

A summary is given of the fundamental studies being carried out on the mechanical properties of high-purity iron, titanium and its alloys, and the plastic deformation of metals. Other work in progress, e.g. on oxidation equilibria, is briefly mentioned.—MA.

4. CORROSIVE ENVIRONMENTS

4.2 Atmospheric

4.2.3, 6.1

Corrosion Characteristics of Various Duct Materials. J. W. MCWILLIAMS. Eastman Kodak Co. Paper before Chem. Eng'g. Conf., 14th Ann. Mtg. Ind. Hygiene Fdn. *Heating & Ventilating,* **48,** No. 7, 85-86 (1951) July.

Ductwork for handling the exhaust of fumes from open tank operations is subject to a variety of corrosion influences. Limitations of materials such as stainless steel, wrought iron, plywood, asbestos wool may be overcome by protective coatings. A summary of the resistance to corrosion of materials, including Monel, used for exhaust fans, hoods and ducts is given in table form with a rating for each material.—INCO.

4.2.5, 5.9.3, 5.4.5, 8.9.4

Protection of Rails from Salt-Air Corrosion. *Ry. Age,* **130,** No. 7, 21-23 (1951) Feb. 19.

Open track of the Great Northern is subject to the corrosive effects of salt air along the Pacific Coast. The method used to protect the rails consists of flame-cleaning the rails and fittings with oxyacetylene cleaning heads and then coating them with a corrosion resistant product. This paint is reported to have high adhesive qualities that resists cracking, chipping and peeling.—INCO.

4.6 Water and Steam

4.6.4, 1.3, 5.8.2, 5.7.1, 7.4.2

Treatment of Recirculated Cooling Water. J. K. RICE. A paper presented at the Eighth Annual Conference, National Association of Corrosion Engineers, Galveston, Texas, March 10-14, 1952. *Corrosion,* **8,** No. 11, 375-380 (1952) Nov.

A comprehensive review of the published work since 1940 on the treatment of recirculated cooling water is presented. The results indicate that the level of knowledge concerning all the variables in the treatment of recirculated cooling water is about the same as the level of knowledge that existed 25 years ago in the internal treatment of boilers. For each of the several popular methods of treatment there can be shown many instances of both success and failure under apparently similar conditions. Considerable effort is presently being expended, however, in evaluating the relative effect of the variables involved and the next several years should see marked progress.

5. PREVENTIVE MEASURES

5.1 General

5.1

Fundamental Researches on Corrosion and Their Importance to the Engineer. U. R. EVANS. *Engineering,* **171,** No. 4446, 443-4 (1951).

An abridgment of a lecture. Studies on corrosion that have been made at Cambridge and other places are reviewed. A number of anti-corrosive methods which are beneficial if rightly applied can, however, intensify attack if wrongly applied. The phenomena of corrosion due to different causes and the value of various remedies are discussed. Most paint coats are pervious to water and oxygen but the electro-chemical process of corrosion involves movement of ions which takes place slowly and slows down rusting. Experiments with zinc-rich polystyrene paints show that they may be useful where scale has not entirely been removed. Experiments on the use of aluminum primer paints compared with zinc-rich paints have proved somewhat contradictory.—RPI.

5.2 Cathodic Protection

5.2.3, 6.2.3, 4.5.2, 2.3.5

Potential and Current Requirements for the Cathodic Protection of Steel in Soils. W. J. SCHWERDTFEGER AND O. N. MCDORMAN. National Bureau of Standards, Washington, D. C. A paper presented at the Seventh Annual Conference, National Association of Corrosion Engineers, New York, N. Y., March 13-16, 1951. Reprinted from *J. of Res. Nat. Bur. Standards,* **47,** No. 2, 104-112 (1951) August. *Corrosion,* **8,** No. 11, 391-400 (1952) Nov.

Potentials of steel in 20 airfree soils varying in pH from 2.9 to 9.6 were determined in the laboratory. These data and the potential-pH relation for the hydrogen electrode were used in fixing the optimum potential for the cathodic protection of the steel against corrosion. The effectiveness of this potential for the cathodic protection of steel in soils was confirmed by weight loss measurements on electrodes which were maintained at the selected potential in five corrosive soils. Cathodic polarization curves are interpreted in terms of the potential and current requirements for the cathodic protection of steel in soils.

5.3 Metallic Coatings

5.3.2, 5.9.4

Alloyed Chromized Coatings. *Products Finishing* (London), **4,** No. 4, 58-59 (1951).

A note on the production of alloyed coatings by modifications of the chromizing process. Typical coatings considered include: chromium-aluminum, chromium-zirconium, chromium-silicon, etc.—MA.

5.3.4

Hot Dip Galvanizing. WALLACE G. IMHOFF. *Ind. Gas,* **29,** 6-7, 22-25, 27 (1951) June.

Most discussions of hot-dip galvanizing pot failure are about failures that occur at the dross line, or in the lower half of the pot; there is almost no mention of the causes of failure at the top of the pot. Emphasis is on shortcomings of the old sal ammoniac-muriatic acid dip flux technique still used by many companies. Use of zinc ammonium chloride is recommended. Other causes of failure are briefly mentioned.—BLR.

5.4 Non-Metallic Coatings and Paints

5.4.5

Results of Tests on Paints Applied to Steel Under Sub-Marine Conditions. W. HUSSE. *Chem. Tech., Berlin,* **2,** No. 4, 126-128 (1950); *Peintures pigments vernis,* **26,** No. 12, 531 (1950).

Coal tar pitch mixed with asbestine or slate powder was superior to bitumen. Paints based on red lead were the best if left to dry for a sufficiently long time. Chlorinated rubber remains the best synthetic medium.—RPI.

5.4.5, 2.3.1

Laboratory Corrosion Testing of Chemical-Resistant Paints. R. R. ROGERS AND W. DINGLEY. *Finish,* **7,** No. 11, 23-26, 75-76 (1950).

A comparison of corrosion-resistant coatings with ordinary paints has shown that, when the latter are properly selected, they are satisfactory for protection of steel structures under a wide variety of corrosive conditions.—RPI.

5.4.5, 3.5.7, 5.11

Vacuum Facilities for the Study of Supersonic Flow. GEORGE J. MASLACH. Institute of Engineering Research, University of California, Berkeley, Calif. Paper, French Lick Meeting, American Institute of Chemical Engineers, French Lick, Indiana, May 13, 1952.

The problems associated with the design of vacuum structures, whether they be wind tunnels or stills, both require an understanding of structural design and sealing techniques and instruments used to measure pressures in low density wind tunnels can be used to measure other pressures of low magnitude. Special precautions were necessary in building the wind tunnel to prevent leaks through welds and gaskets. Not only did the shell have to be completely tight, but special consideration had to be given to the metals out of which the tunnel was fabricated. Rolled or forged alloys were used since cast materials would be too porous at the vacuums used. The formation of oxides or rust on the inside of the tunnel create unfavorable test conditions since the oxide layer would take up moisture which would be emitted slowly over a long period of time. Low vapor pressure paints and varnishes were used throughout the tunnel after the metal had been thoroughly cleaned.

5.4.5, 4.6.1

Coatings for Protection of Steel in Water. G. W. OXLEY. *Paint & Varnish Production,* **41,** No. 3, 10-13 (1951).

The uses and limitations of various paint systems for underwater service are described. Bituminous and petrolatum media are chiefly discussed, but mention is made of inorganic and synthetic rubber coatings.—RPI.

5.4.5, 4.6.7

The Evaluation of Vinyl Coatings for Surfaces Subject to Fresh Water Immersion. J. L. ROHWEDDER AND F. W.

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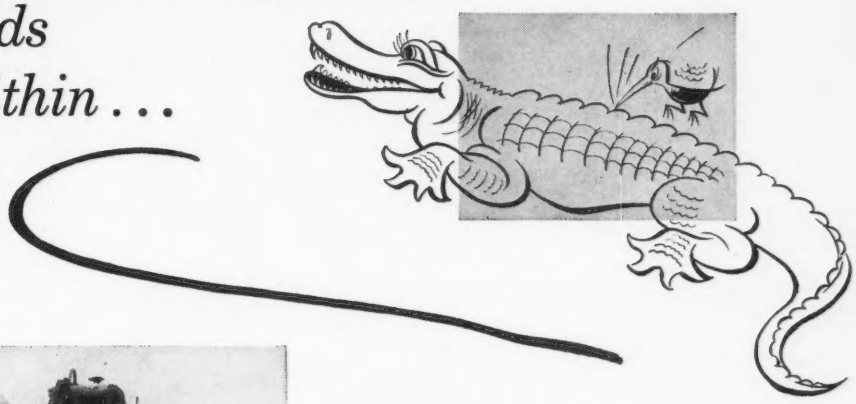

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SHANKS. *Paint and Varnish Production,* **41,** 19-22, 34 (1951) July.

Describes and illustrates method used by Rock Island District, Corps of Engineers for evaluation of coatings for structural steel components.—BLR.

5.4.5, 6.3.19

Technical Facts About Rexton Finishes. Leaflet from Rexton Finishes, Inc., Irvington, N. J., 3 pp. 1951.

Describes 'Rexadhere' a plastic resin coating of special adhesion and flexibility, available for zinc surfaces in satin or gloss black, light grey, gun metal, zinc yellow and clear. The coatings are air dried or heat cured at temperatures up to 300° F. (15 minutes) and very good resistance to salt spray testing is claimed.—ZDA.

5.4.7

Roller Coating Speeds Production. JOHN E. HYLER. *Organic Finishing,* **12,** 15-16 (1951) July.

A process for painting metal and wooden strip.—MR.

5.7 Treatment of Medium

5.7.9, 8.4.2

Removal of Hydrogen Sulfide from Industrial Gases. R. M. REED AND N. C. UPDEGRAFF. Girdler Corp. *Ind. and Eng. Chem.,* **42,** 2269-2277 (1950) Nov.

The various commercial processes for removing hydrogen sulfide from natural and manufactured gases are reviewed. These include 1) the dry iron oxide process; 2) the wet non-regenerative processes, including caustic soda, lime slurry, potassium permanganate and bichromate-zinc sulfate; 3) the Seaboard regenerative non-recovery process; 4) regenerative process with recovery as hydrogen sulfide, including vacuum carbonate, Girbitol, phosphate, Alkazid and phenolate and 5) the Thylox regenerative processes with recovery as sulfur. 34 references.

5.8 Inhibitors and Passivators

5.8.2, 2.3.4, 4.6.9, 8.4.3

A Hydrogen Evolution Method for Evaluation of Corrosion Inhibitors for Oil Wells. WILLARD R. SCOTT AND GILSON H. ROHRBACK. California Research Corporation, La Habra, Calif. *Corrosion,* 8, No. 7, 234-240 (1952) July.

A method of inhibitor evaluation based on measurement of hydrogen evolved during corrosion, apparatus used, evaluation procedure and typical test results are given. The method was developed to simulate oil well corrosion as closely as possible and still give rapid evaluation results. Hot brine is passed continuously by an iron coupon and subsequently discharged from the system to prevent build-up of corrosion products. Simulation of fluid flow is accomplished by rotating the sample and provision is made for introduction of a gas in the brine. The gas and liquid leaving the iron coupon are separated and the amount of hydrogen in the gas stream determined. This provides a means of continuously measuring the rate of hydrogen evolution and consequently of the corrosion rate. Effect of a chemical on this rate is determined by injecting it into the flow stream in front of the sample and recording the change in rate of hydrogen evolution. Oil is not used in the liquid stream because oil well corrosion is an ionic process and occurs only when metal is in contact with water.

5.8.2, 4.6.1, 6.2.1

Corrosion: New Rust Preventives. WILLIAM D. ROBERTSON. *Chem. Eng.,* **57,** 290, 292 (1950) April.

Use of sodium and potassium molybdates or tungstates dissolved in small concentrations in circulating water to prevent corrosion of iron and steel.—MR.

5.8.2, 4.6.10, 8.9.4

Anti-Corrosion Compound Developed by Canadian National. *Ry. Age,* **130,** No. 16, 42 (1951) Apr. 23.

A new anti-corrosion compound is being tested on three refrigerator cars. If results obtained in laboratory tests, which indicate the inhibitor is capable of arresting 78-95% of the corrosive action of brine and water, can be duplicated in actual operations, it is expected that annual savings in cost of refrigerator-car maintenance will reach $500,000. The inhibitor is composed of sodium hexametaphosphate and powdered calcium chloride and is placed in car bunkers in proportion to amounts of ice and brine. Because it is only partially expended in the refrigeration process, the surplus inhibitor will tend to reduce corrosion of track and bridge structures caused by brine and water drip.—INCO.

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5.8.3

Wetting of Metals by Water. (In German.) J. L. VON EICHBORN. *Werkstoffe u. Korrosion*, **2**, No. 6, 212-221 (1951) June.

A survey of the literature with some experiments by the author. Wetting and free boundary surface energy; the contact angle of water/air on gold and silver; wetting hysteresis and adhering traces of water drops on mercury; phenomena on platinum, nickel, brass, copper, zinc; combination with air, adsorptive or oxidative; "adsorptive power" and surface tension of metals; adhering traces of water cover. Bibliography of 33 references.—BNF.

5.8.3, 6.2.2

Mechanism of Protection of Iron from Corrosion by Sodium Nitrite. (In Russian.) I. L. ROSENFEL'D. *Doklady Akad. Nauk S.S.S.R.*, **78**, No. 3, 523-526 (1951) May 21.

Investigation of the effect of sodium nitrite on anodic and cathodic processes; bath composition was 0.1 normal sodium chloride, 0.005 molar sodium carbonate, 0.005 molar sodium bicarbonate, pH 9. It was concluded that sodium nitrite was an anodic inhibitor.—BNF.

5.9 Surface Treatment

5.9.4

Chromate Coating Process for Zinc and Cadmium. *Machinery*, **57**, No. 12, 182 (1951) Aug.

Announcement has been made of a process called "Enthox" for producing chromate coatings on zinc and cadmium plate and zinc-base alloys. The process operated at room temperature uses from 1 to 2 oz. of salt per gallon of water. After a few seconds immersion, an adherent chromate coating is produced on the piece to be coated. "Enthox" coatings serve as bases for organic finishes, including paints, enamels and lacquers.—INCO.

5.9.4, 2.3.9

Phosphate Coatings on Steel. Part II. X-Ray Diffraction Study of the Phosphates of Zinc, Iron and Manganese. J. B. BURBANK (PB 100514) 30 pp. (July, 1949) Mimeo.—$0.75; *Bib. Tech. Rept.*, **14**, No. 2, 81 (1950) Aug. 11.

Extension of available X-ray defraction data to include zinc, iron and manganese phosphates after encountered in phosphating processes and coatings. X-ray defraction patterns of ten phosphates established. These and those already established combine to make a comprehensive series of the neutral and acid phosphates of these materials.

5.9.4, 6.3.1

Chromate Finishes in War and Peace. H. C. IRVIN. *Metal Finishing*, **49**, 109-113 (1951) July.

Discusses nature and properties of chromate films, their application to various metals, their corrosion resistance and appearance, their use as paint bases, their mechanisms of action, formulation of chromate baths and bath variations required by processing limitations. They are applied to zinc, cadmium, aluminum, copper, brass and bronze.—BLR.

6. MATERIALS OF CONSTRUCTION

6.1 General

6.1, 4.4.2

Materials of Construction Versus Citric Acid. *Chem. Eng.*, **58**, No. 3, 211-212+ (1951) Mar.

Discussion includes comments on:
1) "Worthite," W. E. Pratt;
2) "Coatings," K. Tator;
3) "Cements," R. B. Seymour;
4) "Wood," H. B. Smith, III;
5) "Glass-Lined Steel," S. W. McCann;
6) "Lead," K. H. Roll;
7) "Rubber Lining," J. P. McNamee;
8) "Porcelain," W. V. Lapp;
9) "Silicones," J. A. McHard & J. T. McIntrye;
10) "Tantalum," L. R. Scribner;
11) "Iron & Steel," A. W. Spitz;
12) "Durimet 20," W. A. Luce;
13) "Chlorimets," W. A. Luce;
14) "High-Silicon Irons," W. A. Luce;
15) "Aluminum," A. B. McKee, A. Fitz, & D. J. Fetchko;
16) "Stainless Steel," G. L. Snair, Jr.
17) "Nickel & Nickel Alloys," W. Z. Friend;
18) "Carbon," J. F. Revilock;
19) "Stoneware," F. E. Herstein.
—INCO.

6.1, 4.4.3

Materials of Construction Versus Phenol. *Chem. Eng.*, **58**, No. 8, 222, 224, 226, 228 (1951) Aug.

Papers include: 1) "Nickel and Nickel

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6.1, 5.1

Materials Development. *Product Eng.*, **22,** No. 5, 154-166 (1951) May.

Section on trends in plastics discusses rubber-plastic blends, large-molded parts, exthoxyline resins, fluorine plastics, cellulose plastics, nylon, and reinforced plactics. Improvements are expected in stainless and alloy steels in the light weight metals, in currently available super alloys and in protective coatings for high-temperature service and corrosion resistance. Section on advances in metals discusses alloy steels, aluminum, magnesium-base alloy, titanium, zinc, molybdenum, and tantalum. Section on new ceramics as aids in the advances in high temperature coatings and new ceramic dielectrics. Also discussed are silicon finishes, hot spraying, steam spraying, fungicidal varnishes and lacquers and new vinyl coatings.—INCO.

6.1, 5.11

How to Overcome Materials Shortages in Product Design and Manufacture. H. R. CLAUSER. *Materials & Methods,* **34,** No. 1, 89-112H (1951) July.

Ways to stretch scarce materials, as simplification of design, reduction and reclamation of scrap, hard-facing, use of composite materials, and the substitution of clad nickel, Monel, Inconel, stainless steel, copper-nickel, or copper for the solid metals for use between —50° and 1000°F are discussed. A cladding of 10 nickel on each side of carbon-steel replaces solid nickel for some electronic tube applications. Aluminum-clad low-carbon steel is substituted for nickel anodes in radio tubes. The conservation of nickel by nickel-silver powder, nickel-cladding, and substituting of stainless steel, porcelain enameled steel, glass, and corrosion resistant coatings for nickel and nickel alloys, and the conservation of nickel in plating are discussed. The conservation of corrosion and heat resistant stainless steels and irons by the use of NE steels, and the saving of columbium, zinc, chromium, cobalt, wolfram (tungsten), cadmium, molybdenum, and manganese are described. Cast and malleable iron is used instead of aluminum for automotive parts. Tables are given of alternates for scarce materials for specific applications.—INCO.

6.2 Ferrous Metals and Alloys

6.2.1, 5.9.2, 5.8.2

Corrosion Pickling, Inhibitors and and Passivation of Metals (or Oxidation, Deoxidation and Anti-Oxidation). J. FRASCH. *Metaux., Corrosion-Industries,* **26,** 81-94 (1951) Feb.

Corrosion of iron and its alloys. Nature of iron oxides formed during corrosion, roles of oxygen and of hydrogen corrosion of iron, pickling of ferrous materials, inhibitors as protection against corrosion, and passivation of iron by means of gelatine treated with bichromate are discussed.—INCO.

6.2.2

Corrosion Behavior of Ferritic and Pearlitic Cast Iron Containing Spheroidal Graphite; A Critical Discussion. (In German.) E. FRANKE. *Werkstoffe u. Korrosion,* **2,** 101-103 (1951) Mar.

Data indicate that neither quantity nor form of graphite in cast iron has any marked effect on resistance to corrosion. Includes tables. 19 references.—BLR.

6.2.2

Nodular Iron's Record—Two Years Later. *Steel,* **127,** 85-89, 100 (1950) July 17.

Performance data gradually accumulated presage a strong role for nodular graphite cast iron as an engineering material. Results of experimental work and some facts as to how the new material stands up under service conditions are summarized. Experiences of ten U. S. companies.—MR.

6.2.3, 3.2.2, 8.4.3

Hydrogen Attack of Steel in Refinery Equipment. R. T. EFFINGER, M. L. RENQUIST, J. G. WILSON, AND A. WACHTER. Shell Oil Co. Paper before API, Div. of Refining, 16th Mid-Yr. Mtg. Tulsa, May 1, 1951. *Petroleum Processing,* **6,** No. 5, 500-504 (1951) May.

A corrosion prevention program for process equipment, particularly in catalytic cracking gas plants, based on studies of Shell Oil Co. As a result of the survey, the following facts were established: Hydrogen attack is experienced in environments where free-water phases exist, regardless of the temperature and pressure; where there is a wide pH range. An instrument, a membrane type of device, was developed for the detection of environments which promote hydrogen penetration, and for the evaluation of the changes in operating conditions which influence the rate of hydrogen attack. Thorough water washes of the hydrocarbon liquid and gas streams remove water-soluble acidic components while additions of ammonia in some cases increase the pH to safe levels. Specific applications of these corrective measures have been made at the refinery. Tempered-alloy and high carbon steels are more subject to embrittlement than are low-carbon steels. Austenitic grades of stainless steels are satisfactorily resistant to the corrosive environments which promote hydrogen penetration in carbon- and low-alloy steels, while the ferritic grades of stainless steels are not suitable. —INCO.

6.2.3, 4.3.2, 5.8.2

Dependence of the Rate of Dissolution of Steel in Sulphuric Acid upon the Pressure. (In Russian.) S. A. BALEZIN AND A. G. TULAEVA. *Doklady Akad. Nauk S.S.S.R.,* **78,** No. 1, 75-77 (1951) May 1.

Experiments made using 5 normal sulfuric acid containing inhibitors or stimulants. In the presence of inhibitors, pressure had little influence on the rate of reaction.—BNF.

6.2.5, 3.7.2, 3.7.4

Corrosion—The Sigma Phase in Stainless Steels. M. G. FONTANA. *Ind. & Eng. Chem.,* **43,** No. 7, 91A-92A (1951) July.

The sigma phase occurs in stainless steels more readily if the steel contains ferrite. Lowering the nickel or increasing the molybdenum or silicon produces some ferrite rather than a totally austenitic steel. The formation and mechanical properties of sigma phase are given. Areas adjacent to the sigma formation are depleted of their chromium and will be subject to corrosion. Sigma is not expected to be subject to corrosion more than austenitic stainless steel because of its high chromium content. More work must be done on its resistance to specific corrosives.—INCO.

6.2.5

What Do You Know About Stainless? Part I. HOWARD E. BOYER. *Steel Processing,* **37,** 287-292, 345-349 (1951) June, July.

Discusses the various types of stainless steel, their compositions, properties and microstructures.—BLR.

6.2.5, 3.5.9, 3.7.4

18-8 Can Be Cured After Intergranular Attack. R. N. GILLMORE. *Iron Age,* **168,** 81-85 (1951) Aug. 2.

Intergranular attack of 18-8 can be cured by holding for long periods of time in the sensitizing temperature range. Chromium diffusion from the unaffected areas into the impoverished grain-boundary areas, rather than dissolving the precipitated chromium carbides, apparently causes the cure. Includes photomicrographs.—MR.

6.2.5, 6.3.21, 3.5.9

Cerium Increases Use of Wrought Stainless. *Iron Age,* **167,** 106, No. 23 (1951) June 7; *Steel,* **128,** No. 23, 98 (1951) June 4.

Possibilities of increasing mill yields from ingot to hot-rolled bars, plates, tubes and forgings of corrosion and heat resistant steels are claimed by a development of Carpenter Steel Co. This is made possible because the new range of cerium bearing alloys promotes greater hot ductility and reduces rejects. Forgers get the benefits of better hot-working, fewer cracks and tears, as well as better finishes requiring less machine cleanup. The invention applies to ferrous alloys containing nickel and one or more of the elements of chromium, molybdenum, cobalt, copper, wolfram (tungsten), silicon, manganese, columbium and vanadium. It transforms these alloys into products that can be readily hot-worked and turned out in greater quantities by existing mill facilities. Those Carpenter corrosion and heat resistant grades included in the new cerium bearing alloy range, and patented as such, include stainless AISI types 309, 310, 316, 317, 330 and Carpenter stainless 20 and austenitic valve steels. The invention applies not only to ferrous alloys containing more than 50% iron but also to nonferrous alloys containing little or no iron.—INCO.

6.2.5, 6.3.6, 5.3.4

Stainless on Copper Halts Lithium Attack. *Iron Age,* **168,** No. 7, 114 (1951) Aug. 16.

Tests made at Oak Ridge National Laboratory show that spraying stainless steel on copper will protect it from the corrosive action of lithium. The work was performed for the Atomic Energy Commission by W. K. Prater and L. O. Love of Union Carbide Corp. To enrich the stable isotopes of lithium by the electromagnetic process it was desirable to use the lithium metal as charge material. Initial results indicated that the corrosive action of the hot lithium metal, especially on the copper castings of the source unit,

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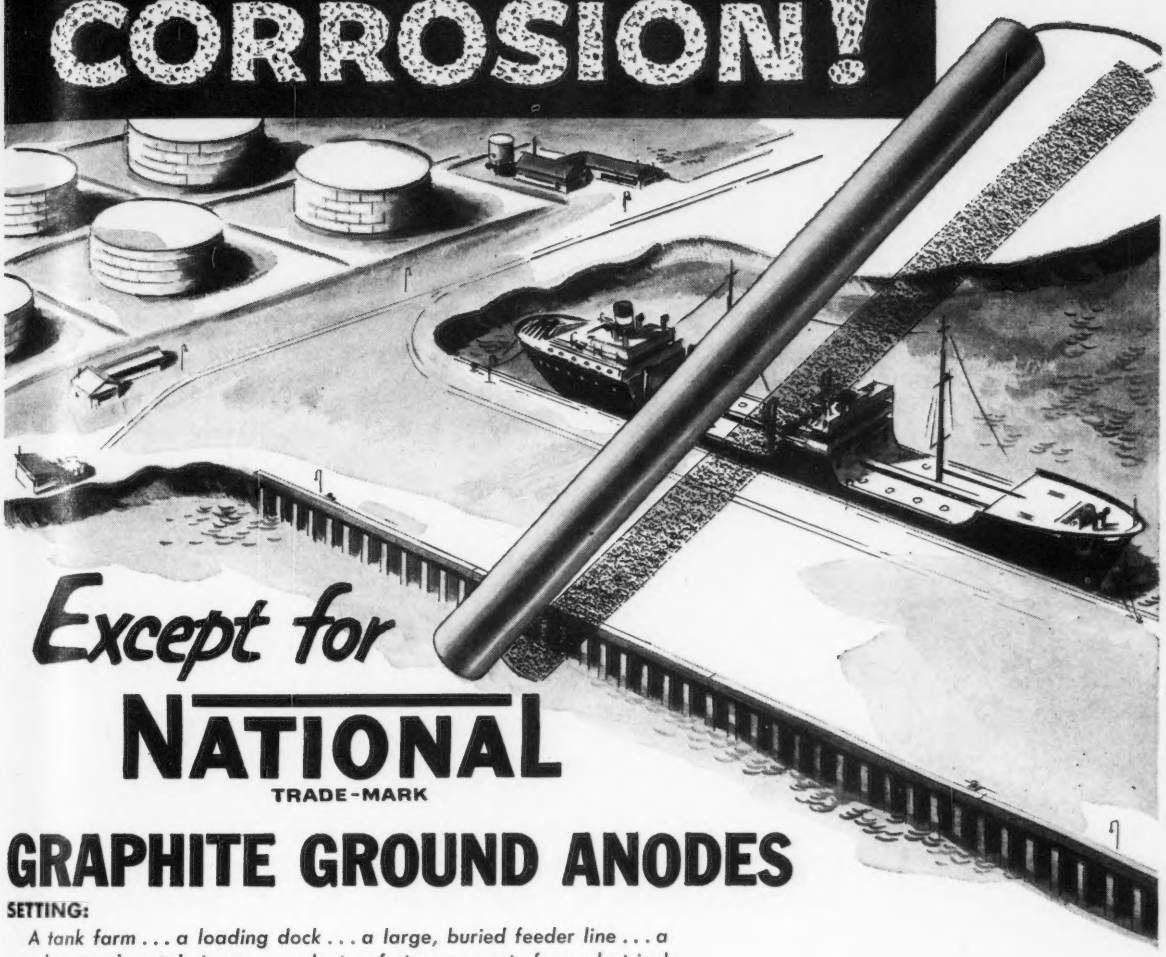

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would preclude its use unless some method of protecting the castings could be found. The non-corrosive properties of iron suggested the possibility of coating parts affected by the lithium metal with non-magnetic stainless steel. They were sand blasted and sprayed with stainless steel, coating the parts approximately 0.015 inch thick, using a metal spray gun. Of more than 100 runs in which coated castings were used no failures occurred due to corrosion of the castings. Castings sprayed with stainless steel have also been used with equally good results in the processing of potassium metal.—INCO.

6.2.5, 7.1

Some Proven Gas-Turbine Steels and Related Developments. D. A. OLIVER AND G. T. HARRIS. Iron and Steel Institute. 'Symposium on High Temperature Steels and Alloys for Gas Turbines,' 1951, p. 46-59 (TN673 Ir6s.)

An outline is given of developments in special steels for jet engines. The austenitic steels R2O and G18B are discussed and new long-time creep data are presented for times up to 30,000 hours. The ferritic steels including H40 and H46 are reviewed ,and evidence demonstrates the creep-strength superiority of stainless H46 type up to 630°C. Some considerations governing the choice and use of ferritic steels are listed. Discusses steels for cast turbine casings and relaxation-resisting bolts. The influence of gas-atmosphere composition on the oxidation and scaling of different steels is summarized. Concludes with observations on factors governing progress, and current trends in development, and tabulated data on the measured low- and high-temperature properties of some widely used steels. 21 references.—BLR.

6.3 Non-Ferrous Metals and Alloys—Heavy

6.3.3, 7.1

Chromium-Base Alloys for Gas-Turbine Applications. E. A. G. LIDDIARD AND A. H. SULLY. Fulmer Research Inst. Paper, Iron & Steel Institute, London, Feb. 21, 22, 1951. Symposium on High-Temperature Steels and Alloys for Gas Turbines, Feb. 1951, p. 243-245. *Metallurgia,* **43,** No. 298, 166-168, 185-189 (1951) Apr.; *Metal Progress,* **59,** No. 5, 653-656+ (1951) May.

The methods for producing chromium-base alloys are briefly reviewed. Difficulties are encountered in all methods designed to remove oxygen from the metal and to prevent further contamination by oxygen, nitrogen, or carbon. Melting and casting operations must be carried out in a vacuum or in an atmosphere of argon. Certain chromium-base alloys possess a very high level of creep properties at 900°-1,000°C, and are probably superior to any other metallic alloys in this range of temperature. They have the advantage of high resistance to oxidation and a fairly low density, but chromium and its alloys have a low ductility at room temperature. The chromium-base alloys would have a wider application in gas turbine use if the ductility at room temperature could be improved. Photomicrographs. 7 references.—INCO.

6.3.6, 2.3.7, 3.7.2

Stress Corrosion of Cast Bronzes Evaluated. J. T. CLENNY. General Electric Co. *Iron Age,* **167,** No. 25, 85-89 (1951) June 21.

Simple and electrolytic corrosion can often be reduced by surface treatments such as plating or painting. These treatments will also reduce the possibility of stress corrosion, but other methods have often proved to be more effective. A stress-relief anneal at a temperature suitable for the alloy will reduce casting strains as well as quenching and welding stress. Strains induced by poor casting design, oxide or other inclusions, phase segregation, gas porosity, or large volume shrinkage can be overcome only by a critical review of the casting design for the best contour characteristics. This should be followed by a careful appraisal of the casting patterns, so that risers and chill can be located to derive the utmost benefit from unidirectional solidification. Tests of 10 cast copper alloys under stress in ammonia atmosphere indicate that aluminum bronzes (10% aluminum) offer the best resistance. Four different methods of evaluating the test results were used, including the determination of stress corrosion endurance limits and the percentages of loss of tensile strength due separately to stress and corrosion.—TDD.

6.3.6, 2.5, 1.7.1

Report of Committee B-5 on Copper and Copper Alloys, Cast and Wrought. G. H. HARNDEN, chairman. American Society for Testing Materials, Preprint 10, 1951, 29 pages. (TA401 Am35p.)

Includes recommendations affecting standards for copper and copper alloys, cast and wrought; proposed revised standard specifications for steam or valve bronze castings and for composition brass or ounce metal castings; also proposed revised standard mercurous nitrate test for copper and copper alloys.—BLR.

6.3.6, 3.5.8

Advances in Copper and Its Alloys. Part II. JOHN R. FREEMAN, JR. *Canadian Metals,* **14,** 12, 14 (1951) July.

Engineering alloys, stress-corrosion cracking, and research on quality testing.—MR.

6.3.6, 4.6.4, 7.4.2

Dezincification of Aluminum Brass Condenser Tubes Prevented by Chlorination and Cleaning. C. L. BULOW. *Corrosion,* News Section **7,** No. 7, 1 (1951) July.

Brief note. An aluminum brass tube showed continued resistance to polluted river water if kept free from slime by periodic chlorination (sodium hypochlorite) and cleaning.—BNF.

6.3.6, 1.3, 5.3.2

Copper as a Finishing Material: Review of 1950. *Ind. Finishing* (London), **3,** No. 33, 664-667 (1951).

The subjects considered include copper plating, electroforming, the chemical coloring of copper and brass, the corrosion of copper water-pipes and the use of copper alloys in marine service. 21 references.—MA.

6.3.6, 4.6.11, 3.5.3

Corrosion Resisting Characteristics of Iron Modified 90:10 Cupro Nickel Alloy. W. C. STEWART AND F. L. LAQUE. A paper presented at the Eighth Annual Conference, National Association of Corrosion Engineers, Galveston, Texas, March 10-14, 1952. *Corrosion,* **8,** No. 8, 259-277 (1952) Aug.

This paper provides a summary of information on the corrosion resisting characteristics of the iron modified 90/10 cupro nickel alloy which is currently being substituted for cupro nickel alloys of higher nickel content, particularly where resistance to attack by salt water is required. Following a brief review of the history of the alloy, information is included on the influence of iron content and heat treatment. Behavior of the alloy under several conditions of exposure to attack by sea water will be described. These conditions will include quiet immersion, exposure at moderate velocity and at high velocity. With regard to the latter, data are presented as secured by jet impingement tests, erosion tests of various sorts, tests in model condensers and in piping systems. The article includes information on fouling characteristics and galvanic behavior.

In addition to data referring to clean sea water, some experiences in sulfide polluted water are described. Appended also is available information on behavior of the alloy in corrosive media other than salt water. Appropriate attention is given welded and brazed joints, and some information is included on physical and mechanical properties and heat transfer characteristics of the alloy.

6.3.10

Hastelloy Alloys. (In German.) E. FRANKE. *Werkstoffe u. Korrosion,* **2,** 140-149 (1951) Apr.

Compositions, properties, and uses of four different Hastelloys, with special emphasis on their chemical resistance to corrosion. 23 references.—MR.

6.3.10, 6.3.14

Electrodeposited Tin-Nickel Alloy Castings. N. PARKINSON, S. C. BRITTON, AND R. M. ANGLES. *Sheet Metal Inds.,* **28,** 757-770 (1951) August.

Summarizes recent papers presented to the Electrodepositors' Technical Society on the electrodeposition and corrosion resistance of tin-nickel alloy. Corrosion and tarnish resistance of this new alloy coating is at least comparable with the traditional chromium on nickel.—BLR.

6.3.11, 4.2.1

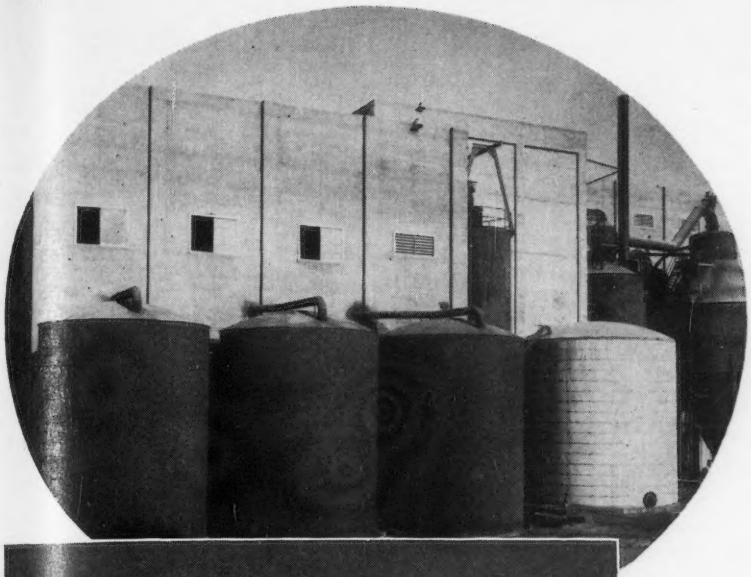
Tarnished [Silver-Plated] Tableware. H. H. SYMONDS. *Metal Ind.* (London), **78,** No. 6, 113 (1951).

Dark brown and blue spots on the bowls of silver-plated spoons were found to be caused by the penetration of a corrosive atmosphere through minute pinholes in the wrapping paper.—MA.

6.3.14, 6.3.10, 2.2.3, 5.3.2

Corrosion Tests on Tin-Nickel. S. C. BRITTON AND R. M. ANGLES. Paper, Electrodepositors Soc., London 1951. *Metal Ind.* (London), **79,** No. 3, 46-50 (1951) July 20.

The results of corrosion tests on nickel, tin, and 65 tin-35 nickel alloy plated on steel and brass are reported. The complete immunity of the alloy to tarnishing in a wide range of conditions seems to be due to the presence of a protective surface film, and even in unfavorable conditions, the rate of corrosion is slow. Tin-nickel alloy is stable during immersion in alkaline and neutral salt solutions, in non-oxidizing acids down to pH 1.2, and in all oxidizing acids and on exposure to



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severely polluted atmospheres, as sulfur dioxide, or dry atmospheres up to 320°. Corrosion tests were also carried out with 0.0001"-0.001" thick coatings with and without a copper undercoat in salt spray, humidity chamber, sulfur dioxide atmosphere, and suburban area. The tin-nickel coating remained untarnished, but the steel and brass bases were corroded through pores in the plate. This was corrected by a 0.00025"-0.0005" polished copper undercoat, and a 0.0005" tin-nickel plate or a 0.001" plate for severe conditions. The alloy coatings can be used in the decoration, food, and chemical industries.—INCO.

6.3.14, 6.3.10, 2.2.3, 5.3.2

Corrosion Resistance of Electrodeposited Tin-Nickel Alloy. S. C. BRITTON AND R. M. ANGLES. Tin Research Inst. Paper, Electrodepositors Tech. Soc., London, May 21, 1951. *Electroplating*, **4**, No. 6, 201-203 (1951) June.

The corrosion resistance of 65 tin-nickel alloy deposits on brass and steel was studied with a wide range of corrosive agents, including nitric acid, sulfuric acid, sodium hydroxide, and sodium chloride. The effects of deposit thickness and porosity were studied under atmospheric conditions. The results show that tin-nickel deposits will withstand a variety of environments that are corrosive to other metals. Porous deposits on brass or steel can be disfigured by corrosion of the base metal. For moderately severe conditions, a 0.0005 in. deposit should be made on brass. An undercoating is required on steel and a deposit of 0.0005 inch of copper under 0.0005 in. of tin-nickel should withstand moderately severe conditions. This deposit is not inferior to that given by chromium on nickel of a similar thickness. The alloy deposits may have an advantage in that they are tarnish-resistant.—INCO.

6.3.15

Titanium: Huge Expansion for Defense Paves Way for Civilian Use. F. L. CHURCH. *Modern Metals*, **6**, No. 12, 19-21 (1951).

A summary of the potential uses of titanium. The properties which make titanium attractive as a commercial material are briefly reviewed, and the author then considers future applications. Some possible uses include application in the chemical and petroleum industries, for marine application, and in aircraft. Although the usefulness of the material is established, the major factor limiting its commercial exploitation is the rate of production. The author considers that titanium will mature at a much faster rate than either aluminum or magnesium.—MA.

6.3.15

Corrosion Behavior of Titanium and Some Titanium Alloys. F. M. REINHART. U. S. Dept. of Commerce, Natl. Bur. Standards, Progress Report No. 1, Dec. 21, 1950, 22 pp.

Stress corrosion tests in both urban and marine atmospheres were started on carbon-free commercially pure titanium, 0.3 carbon commercially pure titanium, and titanium alloy 125A (1.86 chromium, 0.024 carbon, 0.43 tungsten, 0.94 iron, balance titanium). Stresses were applied longitudinally and transversely to the direction of rolling of the sheet at values of 70, 80, and 90 percent of the yield strengths of the materials. There were no stress corrosion failures after 90 days of exposure. The 0.3 carbon-titanium which was stressed at 90 percent of the transverse yield strength failed by stress rupture in from 8-21 days, with 18.5-30 percent elongation. Panels of carbon-free titanium, after spot welding, arc welding, and in contact with dissimilar metals of 19-9 stainless steel, Monel, aluminum alloys, 4130 steel, and Fs-1H magnesium alloy (0.3 silicon, 0.005 nickel, 0.005 iron, 3.1 aluminum, 1.0 zinc, 0.2 manganese, 0.3 calcium) were exposed in urban and marine atmosphere and in tidewater. The galvanic attack on the magnesium alloy in the titanium-magnesium couples was very severe due to the high current density of the couple. No conclusions were drawn at this time. Photomicrographs.—INCO.

6.3.15, 3.7.3, 5.9.1

How to Work Titanium and Its Alloys. ANDERSON ASHBURN. *Am. Machinist*, **95**, 145-153 (1951) June 11.

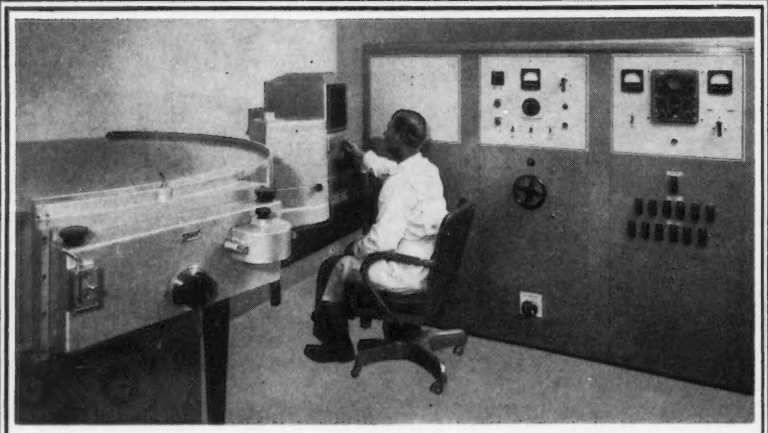
Includes a series of articles on titanium which summarize the information now available. Properties, heat treatment, machining, forging, bending, welding, and descaling and cleaning are discussed.—MR.

6.3.15, 3.7.4, 3.7.2

Minor Uses of the Light Metals: I.—Titanium in Alloys. II.—Titanium in Cast Iron. *Light Metals*, **14**, Nos. 154, 155; 46-49, 89-91 (1951) Jan., Feb.

Part I.—Titanium in aluminum alloys causes grain refinement. Table shows effects on mechanical properties. Titanium also used in iron, nickel-chromium and copper alloys.

Part II.—Titanium produces a fine



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grain size in both grey and white iron. Other effects are also discussed and tables show mechanical properties, corrosion resistance, etc.—BNF.

6.3.15, 5.9.4, 4.3.2

Corrosion Resistance of Anodized and Unanodized Titanium—Effect of Common Mineral Acid Solutions. CHUK-CHING MA AND E. M. PERES, JR. *Ind. and Eng. Chem.*, **43**, No. 3, 675-679 (1951) Mar.

The corrosion rates of anodized and unanodized titanium in acid solutions of various strengths were determined by the alternate immersion corrosion test at 35°C (95°F). All tests were conducted at a cycle of 2 minutes and 38 seconds for 96 hours. In addition, the behavior of anodized and unanodized metals in selected acid solutions at the boiling point were investigated by the total immersion corrosion tests, without aeration. Because no titanium anodization condition was available in the literature, it was necessary to evaluate the protective films formed under various conditions.

A 15-minute treatment at 20°C (68°F) with a current density of 3.6 amperes per square inch at 7 volts in a 15 percent sulphuric acid solution resulted in a film that was satisfactory for the purpose of this investigation. The corrosion resistance of titanium was found to depend more upon the oxidizing, reducing, or "neutral"—i.e., neither oxidizing nor reducing tendencies of the corrosive medium to which it was subjected than upon the concentration of the medium. In oxidizing media both anodized and unanodized titanium were equally resistant to attack at all concentrations and temperatures tested. In reducing media both were readily attacked at about the same rate. In neutral media the anodized metal was at once seen to be superior to the unanodized in resisting attack by acids.—ALL.

6.3.15, 8.9.1

Titanium Tested for Aircraft Use. *Product Eng.*, **22**, No. 3, 153 (1951) Mar.

Titanium and titanium alloys can replace stainless steel in airplanes, with a 43 percent saving and added resistance to corrosion, wherever temperatures above 600° F are not encountered, provided they can be produced with comparable minimum standards. A similar saving in weight will be obtained by the replacement of alloy steels by titanium alloys in the forms of forgings, bar and plate. Machining operations of titanium bar, including drilling, tapping, reaming, turning, milling, grinding and thread chasing, have proved satisfactory. Rivets were successfully formed from titanium wire. Sheet was formed satisfactorily by power-brake, drop-hammer, spinning and Hydropress. operations.—INCO.

6.3.16, 6.3.9, 2.3.7

Behavior of Molybdenum and Tungsten in Low and Medium Temperature Ranges. E. NACHTIGALL. *Powder Met. Bull.*, **6**, 26-31 (1951) Apr.

Considers oxidation behavior, hardness, tensile strength, and elongation of molybdenum and tungsten below 500° C. Data are tabulated and plotted.—BLR.

6.3.19, 2.2.5, 5.9.4

Corrosion Tests With Zinc Alloy Die Castings in Damp Gypsum Plaster. L. A. J. LODDER AND S. BAUMGARTEN. *Metallurgia*, **43**, 273-279 (1951) June.

Occasionally cases of severely corroded zinc-alloy electrical conduit fittings are reported — invariably after prolonged contact with a damp wall. Results of a search for suitable protective measures are presented. It is recommended that a chromate treatment be adopted, and that an auxiliary coating be applied specifically to preserve the chromate coating. —BLR.

6.3.20

Zirconium—Production, Properties, and Alloys. G. L. MILLER. Murex, Ltd. *Metallurgia*, **43**, No. 259, 209-214, 220 (1951) May; *Murex Review*, **1**, No. 8, 184-194 (1951).

The manufacturing methods and properties of zirconium and its alloys are described. The corrosion resistant properties in acids and bases have made zirconium suitable for surgical repair parts. Its activity with oxygen and nitrogen make it an excellent metal for use in the electronic industry. Zirconium has been alloyed with tantalum for tensile and corrosion resistant properties and with nickel up to 7.5% for oxidation resistance. Charts. 9 references.—INCO.

6.3.20

Commercial Uses of Zirconium Developing. G. L. MILLER, Murex Ltd. *Iron Age*, **167**, No. 20, 83-87 (1951) May 17.

Current world production of ductile zirconium as far as is known is confined to the U. S. Bureau of Mines, Foote Mineral Co. and Murex, Ltd. Practically all of the American production is by the Atomic Energy Commission so that the British have been the first to offer the metal to industry in quantities sufficient to determine its commercial possibilities. There has been some production of zirconium metal powder in Germany by the reduction of potassium zirconium fluoride with sodium but no one has claimed the production of ductile metal from this powder, nor from that produced by the calcium reduction of zirconium dioxide. The Kroll process for producing ductile zirconium has been developed rapidly from a laboratory unit to a full-scale production plant and has completely outstripped its rival the Iodide or van Arkel process, which was the first to yield ductile zirconium on a commercial scale. The two processes are quite different in every respect except that a halide is an intermediate in the reduction process. Commercial uses of zirconium are growing. Keen interest has been shown in the possibility of using zirconium in surgery. Tests made by electronic engineers show that for many purposes zirconium is the ideal metal. As a constructional material for chemical plants, there is little doubt that zirconium will find many uses, at first in special parts where the high cost is not an important factor compared to the advantages obtained, and later as the price is reduced by increased production, the metal will become used more generally.—TDD.

6.3.21, 3.4.6, 2.1.1

The Reaction Between Oxygen and Thorium. PASCAL LEVESQUE AND DANIEL CUBICCIOTTI. *J. Am. Chem. Soc.*, **73**, 2028-2031 (1951) May.

A study of the oxidation of thorium was made in order to make comparison with oxidations of other metals of group IVB of the Periodic Table. The reaction was studied in the range 250-700°C. Rate constants for the linear oxidation were measured and energy of activation calculated.—BLR.

6.4 Non-Ferrous Metals and Alloys—Light

6.4.1, 5.5.1, 5.4.5

Surface Protection of Light Metals by Means of Film-Forming Organic Substances. (In German.) G. HOFFMAN. *Metalloberflache*, **5**, sec. A, 61-62 (1951) Apr.

Brief discussion of above includes tabulated comparison of corrosion-resistance of uncoated metal and metal coated with 11 different organic substances.—BLR.

6.4.2, 8.3.5, 8.3.4, 8.3.3, 8.3.2

Durability of Aluminum and Its Alloys —The Food Industry. *Light Metals* (England), **14**, No. 155, 97-102 (1951) Feb.; No. 156, 133-138 (1951); No. 157, 189-194 (1951) Apr.

A few of the more important applications of aluminum in the food industry are considered. The suitability of the properties of aluminum for use in the processing, handling and distribution of food products is discussed. The article is restricted to the aspect of corrosion resistance, but the lightness, good thermal conductivity and ease of fabrication of aluminum are also important for this use. The toxicity of the metal is the most important aspect to be considered. The Mellon Institute of Industrial Research in U. S. A. conducted an investigation over a period of six years which proved that aluminum is not a poisonous metal and does not cause any disease and that aluminum does not accelerate the destruction of vitamins or other food accessory substances during cooking. Aluminum also has no effect on biological processes such as fermentation and is non-toxic to bacteria and moulds. Aluminum also has no effect on the taste of products. Relatively pure aluminum is the standard material used in food industries, the majority being used in sheet form. Many vats, tanks, cooking vessels, pans, trays, kettles, pasteurizing equipment, etc., in the food industries, are made of aluminum. Complete cleanliness of this equipment will minimize the attack of corrosive media, whereas pitting may result if dirt is allowed to accumulate on the aluminum surface. Organic solvents may be used to remove grease, or mild alkaline cleaners which contain an inhibitor. Foods vary considerable in composition and their action on metals may be affected not only by their composition, but also by the presence of various substances added during processing, such as preservatives or flavorings. Colloidal material and sugars frequently have an inhibiting action.

The brewing industry uses aluminum in equipment for various stages of the brewing process, and also for the storage and transport of beer. Applications include fermenting vessels, storage and conditioning tanks, yeast containers and barrels, and miscellaneous items such as pipes. General cleaners for aluminum equipment are discussed, as well as the removal of beer stone, a deposit peculiar to the brewing industry. Pure aluminum provides best resistance to beer.

Anodizing, especially with oxalic acid, has been found to improve the resistance of aluminum and its alloys to beer products.

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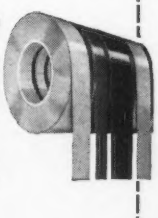

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ability to be fabricated cheaply and easily. Aluminum has proved to be suitable for the following: milk cans, churns, pails, heaters and coolers, pasteurizing plant, strainers, filters, piping, tanks, equipment for manufacturing and distributing cheese, butter and ice-cream and milk bottle caps. The various aluminum alloys do not vary a great deal in their behavior in contact with milk. Aluminum may suffer some attack in contact with sour milk having a marked acid reaction, particularly at high temperatures. Wrought alloys have better resistance than cast ones. The choice of cleaning material is important. Strong caustic soda is efficient but causes considerable attack. Soda ash with a sodium silicate inhibitor causes only negligible attack. Hypochlorite solutions used as cleaners cause a certain amount of attack but Choloramine-T in dilute solution may be used with considerably less attack.

As a result of extensive studies, Reif and Steinbeck have drawn the following conclusions: (1) usually, the purer the aluminum the better the performance; (2) alloys are less resistant to attack than pure aluminum; (3) metal tempered at 380° C (716° F) and 550° C (1022° F) is more resistant than hard-rolled metal; (4) oxalic acid anodizing improves the resistance to attack and is slightly superior to chemical oxidation; (5) the more dilute the fruit juice, the more pronounced will be any attack.

Aluminum has been used, successfully, for boiling pans for jellies and jams and has been very successful in the anodized condition for handling fruit essences. Data on the behavior of a large number of different fruit juices with aluminum, including black and red currants, cherries, strawberries, raspberries, greengages, gooseberries and blackberries show that the attack is negligible at high temperatures. Citrus juices may be safely handled in aluminum equipment at ordinary temperatures, but the concentration of the sulfur dioxide used as a preservative should be controlled. Blackcurrant juice, grape juice, apple juice and tomato juice are among those which are also handled satisfactorily in aluminum equipment.—ALL.

6.4.2, 8.10.3

Mine Cages and Skips Are Being Lightened Throughout the World. J. Reinhold. *Rev. aluminium* (France), **28,** No. 173, 23-27 (1951) Jan.

A survey of the use of weight-saving aluminum alloy mine skips and cages in South Africa, France, Germany, the United States and England reveals that this development is progressing rapidly. In South Africa where the shafts are extremely deep, aluminum alloys are used in the majority of new installations of skips and cages and also in modernizing old installations. Approximately 40 percent of the cages and 30 percent of the skips are of aluminum alloys. Aluminum alloy cages have been used successfully in Germany for twenty years. Aluminum alloy cages and skips offer the following advantages: 1) increase in output per shaft through allowing higher live loads and accelerations; 2) possibility of reaching greater depths without having to change the existing extraction equipment; 3) increase in safety factor; 4) excellent resistance to corrosion when working with sulphur-bearing coal; 5) ability to withstand shocks. Some of the installations of aluminum alloy cages and skips are described and illustrated by photographs.—ALL.

6.4.2, 3.7.2

The Further Development of Al-Zn-Mg Alloys for Use in Sheet Metal and Rivets. (In German.) H. G. Petri, G. Siebel, and H. Vosskuhler. *Metall,* **5,** 47-52 (1951) Feb.

Sheets containing 4.5 percent zinc, 3.5 percent magnesium, 0.3 percent copper, 0.3 percent manganese, 0.15 percent chromium and 0.03 percent vanadium were found to have adequate strength properties; to be almost completely stress-corrosion resistant; but are insufficiently malleable, except when freshly solution annealed. Describes two new alloys with higher malleability, and with satisfactory properties. Tables, graphs and diagrams. 17 references.—BLR.

6.4.2, 8.4.3, 8.9.3, 7.2

Aluminum Alloys for Offshore Pipe Lines. Edward T. Wanderer and Donald O. Sprowls. A paper presented at the Eighth Annual Conference, National Association of Corrosion Engineers, Galveston, Texas, March 10-14, 1952. *Corrosion,* **8,** No. 7, 227-233 (1952) July.

The rapid increase in offshore oil and gas production has intensified the need for a pipe material that will stand up in coastal waters and marshes. Corrosion problems are severe; steel pipe lines require external protection in the form of protective coatings or cathodic protection or both. Resistance of aluminum alloys to marine exposures led to construction of several welded aluminum marine lines, including one in Matagorda Bay, Texas. This 4-inch welded line, 3500 feet long with one-half entirely unprotected, has been carrying natural gas at about 500 psi pressure for 20 months. After this period of service an inspection showed the exterior and interior surfaces of the pipe were in excellent condition. There was no visible concentration of attack at or adjacent to the welds. Performance confirms corrosion results obtained from samples of 3S, 61S and 63S pipe exposed at this site and sheet samples of the same alloys exposed at other sites. These results give promise an unprotected aluminum alloy pipe line will have long service life under these exposure conditions.

Practical techniques have been developed for construction of aluminum marine pipe lines, including welding, launching and anchoring. Indications are that care must be taken not to overstress welds during launching. While limited experience to date shows bare aluminum lines are approximately equal to coated steel lines in first cost, aluminum pipe lines probably have a cost advantage if maintenance costs for steel are included. Additional corrosion and cost data are needed before definite conclusions can be reached regarding the suitability of aluminum pipe for offshore pipe lines.

6.4.2

Wrought Aluminum Alloys. P. O'Keefe. *Materials & Methods,* **33,** No. 6, 89-104 (1951) June.

The nomenclature, alloy composition, available forms, physical and mechanical properties, corrosion and chemical resistance, fabrication, welding, and finishing of aluminum and aluminum alloys are discussed in detail. Young's modulus for steel is 3 times that for aluminum alloys, but aluminum alloys deflect about 1/7 as much as steel. The increased deflection is offset by their increased ability to absorb impact without permanent set. Aluminum alloys 18S (1.7-2.3 nickel) and 32S (0.5-1.3 nickel) possess exceptionally good corrosion resistance at elevated temperatures. Aluminum and its alloys are corrosion and chemical resistant because of the ready formation of an oxide film. When corrosion does occur, it is due to galvanic action.—INCO.

6.4.2, 3.4.4

Surface Reaction Between Aluminum and $HgCl_2$. G. Bolognesi. *Alluminio,* 18, No. 5, 493-497 (1949); *J. Inst. Metals, Metallurgical Abstracts,* **18,** Pt. 9, 607 (1951) May.

The effect of mercuric chloride on 99.5, 99.9 and 99.99 aluminum was studied by electrochemical means. The concentration range of mercuric chloride was N/500 to N/100,000 and two different types of surface polishing were considered. 16 references.—INCO.

6.4.2, 3.6.6

Galvanic Behavior of Aluminum. (In Italian.) L. Cavallaro and Giampaolo Bolognesi. *Metallurgia Italiana,* 43, 13-17 (1951) Jan.

Results of a series of electrochemical measurements on 99.9935 percent aluminum galvanically coupled with different cathode types. The measurements were made in a 3 percent sodium chloride solution, with or without addition of mercuric chloride. Results, compared with those of other measurements, make it possible to derive a particularly low potential for pure aluminum under spontaneous corrosion conditions. The values of theoretical and experimental potentials obtained by various authors are critically discussed. 14 references.—MR.

6.4.2, 3.7.2

The Effect of Copper and Iron on the Corrosion Resistance of Sheets of the Alloy $AlMg_3(Hy_5)$. (In German.) H. G. Petri and G. Siebel. *Metalloberflache,* ser. A, **5,** A84-A93 (1951) June.

Describes tests made with 17 percent aluminum + 5 percent magnesium alloys varying in copper content between 0 and 0.49 percent and in iron content between 0.0005 and 0.50 percent, exposed to sea water and aqueous solutions of 3 percent sodium chloride + 0.1 percent water and 3 percent sodium chloride + 1 percent hydrochloric acid. Results are presented in the form of tables, graphs, and photomicrographs.—BLR.

6.4.2, 3.7.4

Study for Development of New Stabilized High Strength Aluminum Alloys, Final Report. E. H. Kinelski, Cornell Aeronautical Laboratory, Inc. Report KA-496-M-4; U. S. Bureau of Aeronautics Contract NOa(s) 8861 June 1949. 71 p. illus., tables, diagrs.

Attempts to stabilize 24S-type aluminum-copper-magnesium alloys against intergranular corrosion by the addition of alloying elements designed to prevent the formation of different electro-solution potential zones failed; no addition gave the desired effect of lowering the potential of the $CuAl_2$ precipitate at the grain boundary or the potential of the grain center nor did any of the additions except copper appreciably raise the potential of the depleted grain boundary.

Increasing the amount of copper in solid solution with aluminum raised the solution potential of the binary alloy. When the alloy was heat-treated, however, the copper was removed from solid solution by precipitation, and the depleted grain boundary became anodic to the center of the grain and therefore susceptible to intergranular corrosion attack. It is

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doubtful that any chemical addition would maintain the depleted area potential similar to that of the center of the grain after the copper had precipitated out of the solid solution. Accelerated corrosion tests showed that potential differences existed in the micro-structure of all 24S-type alloys studied.

PDC Comment: The micro solution-potential technique developed during this study was described in the first report of the project. [Report KA-496-M-3, 50 l., (June 1948); PDA 7: Met 129 C-839(1)].

6.4.2, 3.7.4, 3.7.3, 3.7.2

Observations on (the Properties and Corrosion-Resistance of) Some Wrought Aluminum-Zinc-Magnesium Alloys. Maurice Cook, R. Chadwick, and N. B. Muir. *J. Inst. Metals*, **79,** Part 5, 293-320 (1951) July.

High-strength aluminum-zinc-magnesium wrought alloys containing up to 12% zinc, 3.5% magnesium, and 3% copper, as well as chromium, manganese, iron, and silicon in amounts of < 1% each, have been investigated with the object of establishing the most suitable range of compositions for bulk manufacture. Macro- and micro-structures, mechanical properties, resistance to corrosion, and thermal treatments were studied on materials produced on an experimental scale. In addition, the freezing characteristics of the alloys were investigated to ascertain compositions with small eutectic contents and, hence, desirable casting properties. As a result of these studies limiting compositions were established for alloys which possessed optimum mechanical properties and corrosion-resistance, together with the desired freezing characteristics. A comparison was then made, under manufacturing conditions, of the casting and extrusion characteristics of two alloys with similar mechanical properties in the wrought condition, the one having a small and the other a large eutectic content. The superiority of the former, from the point of view of casting and working, was confirmed. This alloy contained nominally zinc 6.5, magnesium 1.8, copper 1.5, manganese 0.25, and chromium 0.25%, and further observations on the effect of different heat-treatment procedures were made on an alloy of similar composition produced on a manufacturing scale in the form of rolled sheet. On this material the effects of cold work and secondary heat-treatment were also investigated to establish conditions for developing maximum corrosion-resistance compatible with high strength and a reasonable measure of ductility.—MA.

6.4.2, 5.3.4, 2.3.5

Electrochemical Measurements of Clad Aluminum Alloys. H. C. Cocks, Royal Aircraft Establishment, Tech. Note No. Met. 143, April, 1951, 10 pp.

Describes the preliminary part of an attempt to correlate the results of measurements of electrode potentials of cladding and core materials and of the corrosion currents of couples formed from them in seawater with the results of seawater-spray corrosion tests on the same or similar materials. The sheet materials used were D.T.D. 683 core clad with 99.75 aluminum, D.T.D. 683 core clad with aluminum-1 zinc alloy, D.T.D. 683 (aluminum alloy containing about 5 zinc) unclad D.T.D. 610A (aluminum alloy containing about 5 copper) clad with 99.75 aluminum, aluminum-1 zinc alloy, and 99.75 aluminum.—INCO.

6.4.2, 5.9.2

Detergents for Use in the Aluminium Industry. P. G. Clements. *Light Metals* (England), **14,** No. 155, 104-108 (1951) Feb.

Author recommends use of alkaline degreasing agents such as soda ash (with sodium silicate as an inhibitor) or sodium metasilicate. Cleaning mechanism is briefly discussed. Diagrams show typical plant.—BNF.

6.4.2, 6.3.6

A Versatile Aluminum-Copper-Silicon Alloy. A. P. Penn. *Metal Treatment and Drop Forging,* **18,** 246-248 (1951) June. (A condensation.)

Surveys mechanical properties of the aluminum-copper-silicon alloy known as DTD 424. Covers effect of heat treatment on sand-cast and gravity die-cast pieces; effect of aging; corrosion resistance; and applications.—BLR.

6.4.2, 7.2, 8.1.4

Florida Turns to Sprinkler Irrigation. *Alcoa Digest* (U.S.A.), **15,** No. 21, 1-4 (1951) July 16.

During World War II, owing to the shortage of steel, aluminum pipe was used in sprinkler irrigation equipment by citrus growers of Florida. Savings of 50 per cent in both operating costs and manpower resulted. Aluminum irrigation equipment has been designed from heat-treated aluminum alloys to withstand pressures of over 500 pounds per square inch. With the exception of pump and motor, practically every part of an irrigation system is now constructed of aluminum alloys. Foot valves, butterfly valves, tees, ells, and rotary guns are made principally of aluminum. Fifty per cent of the irrigated farms in Florida are irrigated with aluminum systems.—ALL.

6.4.2, 7.7

New Tower Design Incorporates Corrosion Resistant Crossarms. *Electric Light and Power,* **29,** 76-80 (1951) Mar.

Describes and illustrates use of aluminum-alloy crossarms on high-voltage transmission lines in industrial areas where frequent painting is required. Data are tabulated.—BLR.

6.4.2, 8.8.1

Aluminum and Its Alloys in the Chemical and Processing Industries. S. M. Lawrence. *Ind. Chemist,* **27,** 219-224 (1951) May.

Reviews some of the more recent developments in the utilization of aluminum and its alloys as materials of construction. Presents data on installation, operation, and maintenance.—BLR.

6.4.2, 8.4.3

The Use of Aluminum in Petroleum Refinery Equipment. E. E. Kerns and W. E. Baker. *Petroleum Refiner,* **30,** 123-129 (1951) May.

Reviews some refinery installations of aluminum in tanks, exchangers, instrument tubing, and insulation weatherproofing. Indicates value of aluminum as an economical construction material for refinery equipment. Data on mechanical properties, corrosion experience, etc., are tabulated. 12 references.—BLR.

6.4.2, 8.4.3, 2.2.4

Aluminum's Role in Refinery Equipment. E. E. Kerns and W. E. Baker. Standard Oil Co. Paper before A.P.I., Refining Div. Mtg., Tulsa, May 1951. *Oil & Gas J.*, **50,** No. 11, 87, 98-99 (1951) July 19.

Aluminum and aluminum alloys have been tested for suitability in service in refinery equipment. It is resistant to corrosion of sulfides, NH_3, organic acids, and furfural. It is, however, subject to galvanic corrosion so care must be taken in design. Aluminum alloys were used for storage tank roofs, vent valves, and flame arrestors, but must be insulated from the steel sides. Aluminum weatherproof jacketing on insulation will corrode rapidly if placed over damp asbestos cement, or magnesia insulation. Aluminum pipe was in service 26 months before it failed by internal pitting. It corroded externally when in contact with clay, chlorides, and heavy metals in marshy soil. Steel is again being used for pipes. Aluminum alloy (7-9 tin, 4.5-5.0 copper, 0.8-1.2 nickel) pump and turbine packing failed after 3 months service due to the high temperature steam (600°F) and a pH of 10. Bronze parts were substituted and have lasted 1 year. 12 references.—INCO.

6.4.2, 8.9.3

Aluminum Pipeline in Use 1¼ Years, Shows No Corrosion. *Light Metal Age,* **9,** No. 7 & 8, 20 (1951) Aug.

40-foot bare aluminum bypass installed 17 months ago in the Alabama-Tennessee Natural Gas Company's 8-inch aluminum pipeline was uncovered for inspection. The pipeline showed no sign of discoloration or corrosion of any sort where the bare pipe was in contact with the soil, nor on the inside which carried natural gas.—INCO.

6.4.3, 1.3

A Review of Beryllium and Beryllium Alloys. J. T. Richards. *J. Metals* (U.S.A.), **3,** No. 5, 379-386 (1951) May.

A survey based on over 90 recent references. Properties of beryllium, beryllium-copper; and other beryllium alloys.—BNF.

6.4.4

Preparation of High Purity Magnesium and a Study of the Effect of Non-Metallic and Alkali Metal Impurities on the Corrosion Characteristics of Pure Magnesium; Fifth Quarterly Report; December 1, 1950—February 28, 1951. Dow Chemical Co., Apr. 13, 1951, 36 p. (COO-43).

Corrosion studies of pure magnesium contaminated with various amounts of iron (15 to 680 ppm) and phosphorus (0 to 2900 ppm) indicate that these elements in combination can exhibit either high or low corrosion resistance depending on their ratio. The critical ratio of iron to phosphorus is at approximately 1.0 provided that the iron exceeds 7 ppm. The corrosion data obtained from the carbide and the carbide plus iron contamination studies are inconclusive at this time. A series of sodium sulfate solutions were evaluated as a corrosion medium. Attempts were made to utilize specimens coated with clear lacquer in order to evaluate localized corrosion (high-humidity test) due to intentional additions of nonmetallics to pure magnesium. A number of specimens were given alternate immersion exposures to 3% sodium-chloride for various periods of time and are reported. Earlier purification studies showed the last traces of aluminum to be difficult to remove. The use of pure graphite granules in connection with the usual triple-layer ⅛-in.-screen filter is effective in removing all traces of aluminum from magnesium during the sublimation process. Data on the operation of the new sublimation

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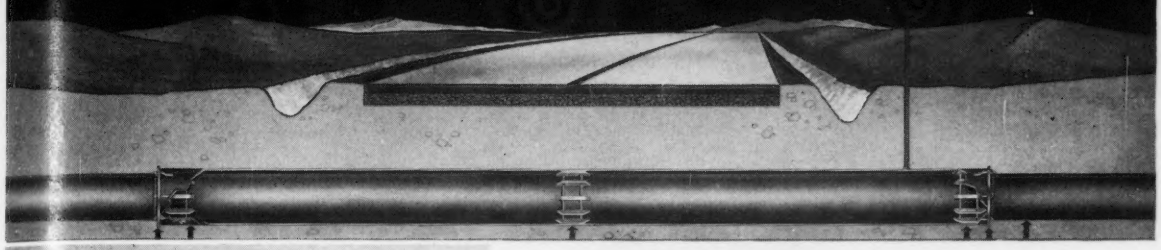

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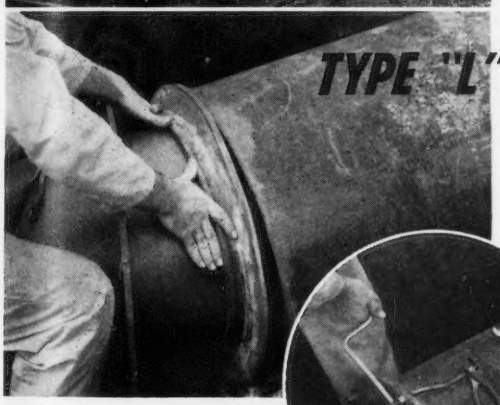

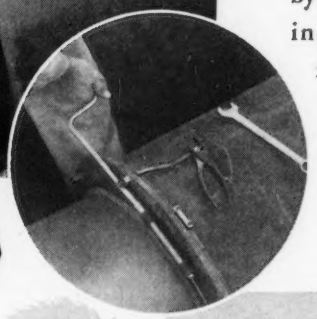

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vacuum casting unit, as well as the analytical results, are presented.—NSA.

6.6 Non-Metallic Materials

6.6.1, 8.8.1

Ceramic Materials for the Chemical Industry. (In German.) WILHELM MIEHR. *Chemie-Ingenieur-Technik*, **23**, 232-240 (1951) May 10.

Comprehensive discussion of refractory and chemically resistant materials deals with a variety of earthenwares, quartzes, and porcelains. Tables and graphs summarize data on composition, production methods, and properties. Includes photographs. 23 references.—BLR.

6.6.5, 5.10, 4.6.11, 2.2.7

Concrete for Sea Water Exposure With Particular Reference to Piling. HERBERT K. COOK, Chief Concrete Research Division, Waterways Experiment Station, Corps of Engineers, U. S. Army, Vicksburg, Mississippi. Reprinted from Proceedings, Wrightsville Beach Marine Conference, June, 1950, where it appeared under the title "Concrete Piles and Their Protection in Harbor Construction." *Corrosion*, **8**, No. 7, 247-250 (1952) July.

Samples of concrete exposed at Treat Island in Cobscook Bay, Maine by the Concrete Research Division of the Waterways Experiment Station, U. S. Army Corps of Engineers are subjected to as many as 14 reversals of freezing and thawing in one week. While influence of seawater sulfates on the concrete is believed to be insignificant at Treat Island the tests indicate conclusively that concrete containing an air-entraining agent is vastly more durable than those which do not contain it. Comparison of Treat Island samples with identical samples exposed at St. Augustine, Fla. indicates that in seawater below 40 degrees F attack on the cement by seawater itself is much less than in seawater of higher temperatures. Tests at St. Augustine indicate cements with more than 8 percent tri-calcium aluminate content will be attacked by seawater more readily than those of lower content. Air entrainment appears to have little effect on attack by sulfates. Seven-sack concrete is superior to five-sack concrete, 7-year seawater tests at Cape Cod show.

A method of encasing wooden piles damaged by marine organisms with concrete is described. The method involves placing a concentric sleeve about the piling, excavating by jets a volume below the mud line, filling the annular space thus created with selected aggregate and then injecting an intrusion mortar.

6.6.6, 3.5.9

High Temperatures; A Refractory Facing for Protecting Mild Steel. *Iron and Steel*, **24**, 336 (1951) July.

Describes a material called "Stoneclad," consisting of a borosilicate matrix containing insoluble refractories. This can be bonded to a metal surface to protect it during long periods of use at high temperatures.—MR.

6.6.6, 3.5.9

High Temperature Heating Elements Which Can Be Operated in Air. G. LEWIN. *Powder Metallurgy Bulletin*, 6, 43-45 (1951) Apr.

Describes ceramic heating elements that can be operated up to 2000° C.—BLR.

6.6.6, 3.5.9

High-Temperature Ceramic Materials. H. B. MICHAELSON, Sylvania Elec. Prod. Corp. *Product Eng.*, **22**, No. 8, 120-123 (1951) Aug.

The chemical and mechanical properties, and uses of refractory ceramics and ceramals are discussed. In refractories, chromium-magnesite brick lasts longer than silica brick and can be operated at higher temperatures. Oxides of cobalt, chromium, and nickel are not used since they are too easily reduced at high temperatures. Hot-pressed combinations of titanium carbide and cobalt or nickel have greater shock resistance and higher tensile strength at high temperatures than oxide ceramics.—INCO.

6.6.6, 3.5.9, 3.4.6

The Oxidation of Silicon at High Temperatures. MERWYN B. BRODSKY AND DANIEL CUBICCIOTTI. *J. Am. Chem. Soc.*, **73**, 3497-3499 (1951) July.

The above was studied between 950° and 1160° C. The metal was found to oxidize very slowly even at high temperatures. An explanation of the logarithmic nature of the reaction is attempted in view of the vitreous nature of the oxide formed. 10 references.—BLR.

6.6.8

So You're Going to Use Plastics. *Modern Industry*, **21**, 44-48 (1951) Feb. 15.

Describes and illustrates a wide variety of plastics applications. Discusses problems to be considered before changing over from metals to plastics. Includes impact of the supply situation and government restrictions.—BLR.

6.6.8, 2.3.2

Effect of Fuel Immersion on Lami-

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Trapped air and gases form blisters that cause damage to the felt shield.

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ASPHALT AND ASBESTOS BUILDING MATERIALS

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nated Plastics. W. A. Crouse, M. Carickhoff and M. A. Fisher. Natl. Bur. Standards. Natl. Advisory Comm. Aeronaut., Tech. Note No. 2377, June 1951, 34 pp.

The effects of cyclic and of continuous immersion in heptane, toluene, and SR-6, a test fuel, on the weight, dimensions, and flexural properties of 19 samples of laminated plastics were determined. No one sample exhibited smaller changes than all other samples in all properties for all fuels and for both cyclic and continuous immersion. The best weight and dimensional stability in the cyclic test were shown by a glass-fabric unsaturated-polyester laminate. The changes in flexural strength as well as in elastic modulus were losses in the majority of cases after the cyclic and continuous immersion tests. The unsaturated-polyester laminates varied widely among themselves in regard to the magnitude of the changes in a given property after an immersion test.—INCO.

6.6.8, 4.3.1, 4.4.1

The Chloride of Polyvinyl Surchloride and Its Use as a Protective Base Against Ultra-Corrosive Chemical Agents. (In French.) Fr. Iiak. *Metaux: Corrosion-Industries*, **26**, No. 309, 233-234 (1951) May.

The copolymer of polyvinyl chloride is a plastic resistant to aggressive chemical agents. It is composed of approximately 87% polyvinyl chloride and 13% polyvinyl acetate. This product, called Vinoflex "N," is resistant to dilute and concentrated acids, both organic and inorganic, to 40% NaOH, rubber chloride, oils and grease.—INCO.

6.6.11, 3.3.1

The Destruction of Wood by Fungi and Its Prevention—Wood Preservation. J. Leutritz, Jr. *Trans. New York Academy of Sciences*, **13**, ser. 2, 177-181 (1951) Mar.

Discusses work on the above, indicating directions of future progress.—BLR.

6.7.2, 5.4.2

Studies of High-Temperature Protection of a Titanium-Carbide Ceramal by Chromium-Type Ceramic Metal Coatings. Dwight G. Moore, Stanley G. Benner, and William N. Harrison. National Advisory Committee for Aeronautics, Technical Note 2386, June 1951, 26 pages. (TL570 Un3t.)

It was demonstrated in earlier work at the National Bureau of Standards that protection against rapid oxidation in jet engines might be achieved by application of a ceramic-metal coating to the ceramal surface. In this earlier work, a coating was developed consisting of 80 parts chromium powder, 20 parts frit (glass), and 5 parts kaolin. When applied to a ceramal of 80% titanium-carbide and 20% cobalt and fired with hydrogen, the coating was found to inhibit oxidation of the ceramal for extended periods at 1800° F. The present investigation was made to gain additional information concerning durability of the coating as affected by frit content firing temperature, firing time and number of coats. In addition, relative effectiveness of the coatings at jet-engine temperatures were studied. Four coatings of varying frit content were prepared and applied to the ceramal. The specimens were then studied with respect to oxidation penetration, transverse breaking load, and thermal shock resistance after prolonged heating in air at 1650, 1800, 2000, and

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2200° F. The variables of firing temperature, firing time, and number of coats were studied for one coating only.—BLR.

6.7 Duplex Materials

6.7.2, 3.5.9

Periodic Status Report No. 22; Fundamental Properties of Metal-Ceramic Mixtures at High Temperatures; Progress During Period August 1 to September 30, 1950. W. B. CRANDALL AND W. G. LAWRENCE. Alfred University. September 30, 1950, 14 pp. (NP-1779).

Pure intermetallics and intermetallic-ceramic mixtures were formed by several methods; for pure intermetallics, hot-pressing, neutral atmosphere firing, flash firing, and spot-welding were carried out. For intermetallic-ceramic systems, thermite reaction, addition, and partial oxidation were used. Oxidation resistance was determined on selected specimens, and an oxidation resistance number was assigned to each. X-ray-diffraction analyses were made on each of 38 specimens and checked. Phase identification is discussed.—NSA.

7. EQUIPMENT

7.1 Engines, Bearings and Turbines

7.1, 3.5.9, 6.2.5, 3.7.2

Development of a High-Temperature Alloy for Gas-Turbine Rotor Blades. G. T. HARRIS AND H. C. CHILD. Wm. Jessop & Sons, Ltd. Paper, Iron & Steel Institute, London, Feb. 21-22, 1951. Symposium on High-Temperature Steels and Alloys for Gas Turbines, Feb. 1951. 67-80; *Metallurgia*, **43**, No. 257, 119-126 (1951) Mar.; *Metal Progress*, 59, No. 5, 653-656+ (1951) May.

The general effect of the carbide-forming elements, wolfram (tungsten), molybdenum, niobium, vanadium, and titanium, the carbon-content, and the composition of the base, on the creep strength at 750-800° C. of austenitic nickel-cobalt-iron-chromium alloys, has been investigated. The optimum creep strength occurred when at least 3 carbide-forming elements were present, when the carbon content and the total percentage of carbide-forming elements were carefully balanced and when the base of the alloy was rich in cobalt. The alloy suitable for gas-turbine rotor blades is Jessop G32 (12 nickel, 45 cobalt, 19 chromium, 2.8 vanadium, 2.0 molybdenum, 1.2 niobium). The optimum heat-treatment of this alloy was oil-quenching from the solidus after a 10 minute soak and fully ageing in the range 750-800° C. Charts.—INCO.

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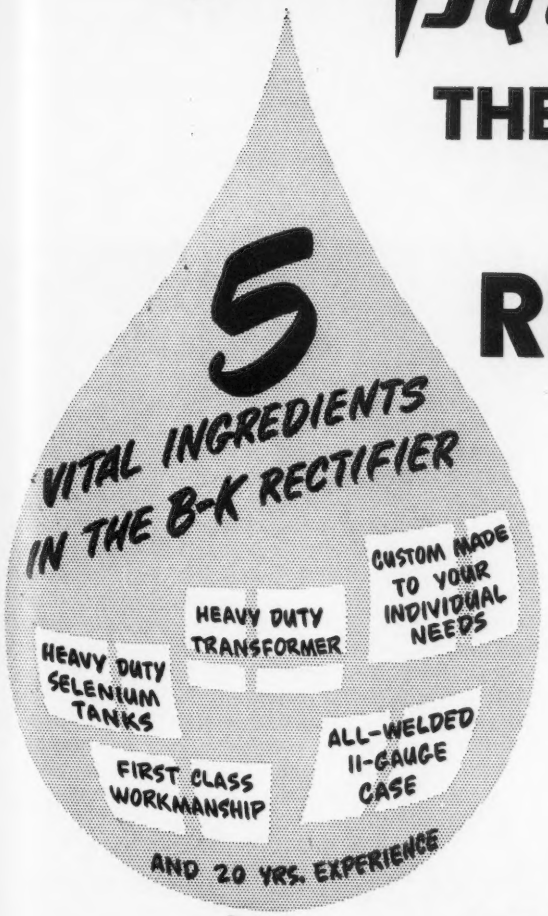

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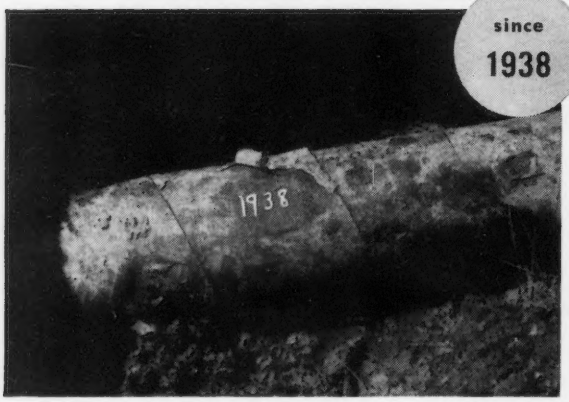

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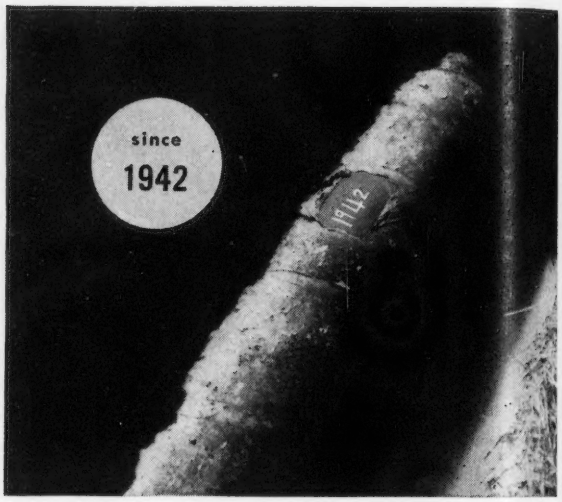

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*Indicates a Junior Member.

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Bloch, Peter K. Stamford, Conn.
Blohm, Clyde L. Los Angeles, Calif.
Bloom, David Cambridge, Mass.
Bloomberg, Arthur Linden, N. J.
Bloomquist, Charles T. Houston, Tex.
Blossom, Edson D. Long Beach, Calif.
Blount, Floyd E. Dallas, Tex.
Blundell, Edwin L. Springfield, Ill.
Bly, Herbert A. Estado Falcon, Venezuela
Boal, John F. Munhall, Pa.
Boaz, Donald P. Downers Grove, Ill.
Boberg Irving E. Chicago, Ill.
Bock, Morris Dallas, Tex.
Bodfish, Howes Baltimore, Md.
Bohne, A. W. Evanston, Ill.
Boies, David B. Chicago, Ill.
Bolling, John G. Evanston, Ill.
Boltz, David C. Long Island City, N. Y.
Bomberger, Howard B., Jr. East Liverpool, Ohio
Bond, Bethel Houston, Tex.
Bond, Donald H. Houston, Tex.
Bond, James V., Jr. New Iberia, La.
Bonner, William A. Wood River, Ill.
Bonnet, Robert W. Lafayette, Ind.
Bonstow, Thomas L. London, England
Booksh, James H., Jr. Lake Charles, La.
Boone, Harold C. Clarendon Hills, Ill.
Booth, Robert C. Houston, Tex.
Boova Augustus A. Kimberton, Pa.
†Borskey, J. W., Jr. Carlsbad, N. M.
Bos, Anton Martinez, Calif.
Bosley, Samuel E. Tulsa, Okla.
Bossert, Earl D. Norristown, Pa.
Bost, Armon H. Tulsa, Okla.
Bostwick, James M. Detroit, Mich.
Bostwick, Thomas W. Jacksonville, Fla.
Bott, Lawrence L. Chicago, Ill.
Botts, Elbert D. Sacramento, Calif.
Boulware, Robert C., Jr. Waynesboro, Va.
Bowan, Walter J. Decatur, Ill.
Bowden, Raymond C., Jr. Pittsburgh, Pa.
Bowen, James V. Los Angeles, Calif.
Bowen, Lloyd O., Jr. Shreveport, La.
†Bowen, Milton M. Cleveland, Ohio
Bowers, Willard R. Elkhart, Ind.
Bowman, William W. Houston, Tex.
Boyce, Trevor G. Houston, Tex.
Boyd, Daniel Montreal, Quebec, Canada
Boyd, George E. New York, N. Y.
Boyd, P. B. Atlanta, Ga.
Boyd, William G., Jr. Galveston, Tex.
Boyer, Myron H. San Francisco, Calif.
Boylan, Francis M. New York, N. Y.
Boylan, James A. Detroit, Mich.
Bozeman, Harry New Iberia, La.
Bradbury, Fred D. Avenal, Calif.
Bradbury, J. E. Chicago, Ill.
Bradfield, George K., Jr. New York, N. Y.
Bradfield, Stephen A. Los Angeles, Calif.
Bradley, Bryant W. Tulsa, Okla.
Bradley, F. E. Los Angeles, Calif.
Brady, Hugh A. Tulsa, Okla.
Brady, James M. Wilmington, Del.
Brady, Merritt H. Emeryville, Calif.
Brady, Thomas E. Owensboro, Ky.
Bragdon Charles R. Larchmont, N. Y.
Bralley, J. C. Cushing, Okla.
Bramble, Lloyd F. South Houston, Tex.
Bramlette, Robert C. Birmingham, Ala.
†Brand, John W. Tulsa, Okla.
Brander, William G. Edmonton Alberta, Canada
Brannan, Joseph C. Shreveport, La.
Brannon, R. A. Houston, Tex.
Branson, Edward H. Rochester, N. Y.
Brasunas, Anton Desales Knoxville, Tenn.
Braun, F. C. Pittsburgh, Pa.
Brecheisen, Charles M. Wichita, Kan.
Brecht, Edwin J. Oil Hill, Kans.
Breeze, Lewis K. Cleveland, Ohio
Bregman, Jacob I. Chicago, Ill.
Breitenbach, Paul El Cerrito, Calif.
Bremer, Clarence New York, N. Y.
Brendel, Robert O. Houston, Tex.
Brennan, John R. Los Nietos, Calif.
Brennan, Thomas J. Houston, Tex.
Breshears, Frank S., Jr. Houston, Tex.
Brich, John G. Pittsburgh, Pa.
Briggs, Gerald F. St. Paul, Minn.
†Briggs, H. L. Los Angeles, Calif.
Briggs, W. R. Philadelphia, Pa.
Brightly, Frederick C., Jr. Oak Park, Ill.
Brinen, Howard F. Racine, Wis.
Brines, M. E. Midland, Mich.
Brink, Edward G. Marcus Hook, Pa.
Britton, H. B. New York, N. Y.
Britton, Orson J. Rochester, N. Y.
Broad, Jacques L. Fort Lauderdale, Fla.
*Brock, James R. Houston, Tex.
Brock, Phil C. Lafayette, La.
Brogan, Lloyd F. Santa Ana, Calif.
Bronstein, Emanuel H. Akron, Ohio
Brooke, W .G. Charlotte, N. C.
Brookes, A. Sidney Newark, N. J.
Brooks, Jerrell Eugene Ashland, Ky.
Brooks, Richard H., Jr. Wichita, Kan.
Brooks, Robert C. Houston, Tex.
Brooks, William B. Freeport, Tex.
Broom, Charles M. Miami, Fla.
†Broome, W. A. Shreveport, La.
Brophy, G. R. Hartford, Conn.
†Brough, Harry R. Salt Lake City, Utah
Broussard, Edward A. Houston, Tex.
Brouwer, Arthur A. Midland, Mich.
Brown, B. F. Raleigh, N. C.
Brown, Charles New York, N. Y.
Brown, Charles D. Houston, Tex.
Brown, Charles G. Brookline, Mass.
Brown, Charles J. New York, N. Y.
Brown, Charles W. Bellaire, Tex.
Brown, Delmar L. Portland, Ore.
Brown, George F. Port Arthur, Tex.
Brown, Gordon W. Brooklyn, N. Y.
Brown, H. D. Tulsa, Okla.
Brown, Harry F. New Haven. Conn.
Brown, Harold H. Appleton, Wis.
Brown, John R. Inglewood, Calif.
Brown, Kenneth W. San Francisco, Calif.
Brown, Marshall H. Wilmington, Del.
Brown, Melvin H. New Kensington, Pa.
Brown, Robert B. Caracas, Venezuela
Brown, Robert G. Tulsa, Okla.
Brown, R. H. New Kensington, Pa.
Brown, Selwyn London, England
Brown, Ual J. Oklahoma City, Okla.
Brown, Vernon M. Lake Charles, La.
Browne, Harry E. Dayton, Ohio
Browne, John J. Taft, Calif.
Brownie, F. A. Calgary Alberta, Canada
†Browning, R. T. Bellville, N. J.
†Broyles, A. C. Tulsa, Okla.
†Broyles, Wayne E. Houston, Tex.
Brudvig, Lloyd A. Houston, Tex.
†Bruhn, H. W. Omaha, Neb.
Brunkow, Ivan L. Tulsa, Okla.
Bruno, Charles A. Marcus Hook, Pa.
Bruse, Wm. E. Elgin, Ill.
Brusse, Lester W. Corpus Christi, Tex.
Brutcher, Henry Eric Altadena, Calif.
†Bruyere, W. H. Houston, Tex.
Bryson, James A. Libertyville, Ill.
Bubsey, Frank J. Columbus, Ohio
Buchan, Rudolph C. Houston, Tex.
Buchanan, William C. Houston, Tex.
Buchoff, Leonard S. Annapolis, Md.
Buck, D. C. Pittsburgh, Pa.
Buckely, Fred S. Des Plaines, Ill.
Buckwalter, John F. Bradford, Pa.
†Buddrus, E. Kansas City, Mo.
Buehler, Martin J. H. Philadelphia, Pa.
Buell, James H. Chicago, Ill.
Buell, Norman S. San Francisco, Calif.
Buensod, A. C. New York, N. Y.
Buettner, Walter J. Chicago, Ill.
†Bullock, Robert L. Shreveport, La.
Bulmer, George A. Hollywood, Calif.
†Bulow, C. L. Bridgeport, Conn.
Bundrant, Charles Ollie Midland, Tex.
Bundy, Alfred D. Cleveland, Ohio
Bunting, William E. Chicago, Ill.
Burbidge, Harrison G. Montreal Quebec, Canada
Burd, Harry G. Granite Quarry, N. C.
†Burden, O. R. Tulsa, Okla.
Burditt, George F. Greensboro, N. C.
Burgbacher, John A. Houston, Tex.
Burgess, Kenneth F., Jr. Freeport, Ill.
Burgess Wilbur T. Omaha, Neb.
Burkholder, John C. Toronto, Ontario, Canada
Burks, Wilbert G. Toronto, Ontario, Canada
Burlingame, M. V. Chicago, Ill.
Burnett, Graydon E. Denver, Colo.
Burnett, William C. Charlotte, N. C.
Burns, Chester P. Pittsburgh, Pa.
Burns, Claude A. Lake Charles, La.
†Burns, D. L. Port Arthur, Tex.
†Burns, Woodrow T. Portland, Ore.
Burnside, Carl B. Neenah, Wis.
†Burton, John T. Salt Lake City, Utah
Burwell, Calvin C. St. Louis, Mo.
†Busby, A .H. W. Trail, B. C., Canada
Busch, Paul E. Kansas City, Kan.
Bush, Frederick J., Jr. Wilmington, Del.
Bush, Richard T. Charleston, W. Va.
*Buss, Onno B. Chicago, Ill.
†Butler, C. A., Jr. Painesville, Ohio
Butler, Edmund R. Chattanooga, Tenn.
Butler, George D. Corpus Christi, Tex.
Butler, R. Everett Detroit, Mich.
Butterbaugh, H. W. Kenosha, Wis.
Butterfield, Pearce R. Linden, N. J.
Butts, Charles E. St. Louis, Mo.
Byarre, Wm. W. Philadelphia, Pa.
*Byars, Harry G. Austin, Tex.
Byer, George T. Lafayette, La.
Byrd, Jack L. Superior, Wis.

C

Caldwell, Edward Henry Niagara Falls, N. Y.
Caldwell, Joseph A. Houston, Tex.
†Caldwell, Marion D. Wilmington, Del.
Cale, Dutro C. Milwaukee, Wis.
Calahan, Melvin C. Tulsa, Okla.
Callander, W. M. Trinidad, B.W.I.
Callaway, Jack C. Tulsa, Okla.
Calvert, R. C. M., Jr. Hilton Village, Va.
Cameron, Joseph A. Jeannette, Pa.
Cameron, William B. Brooklyn, N. Y.

Cameron, William M. Culver City, Calif.
Camp, Eldridge K. East Pittsburgh, Pa.
Camp, E. Q. Baytown, Tex.
Campbell, A. B. Houston, Tex.
Campbell, Harry D. Bakersfield, Calif.
Campbell, John G. Corpus Christi, Tex.
†Campbell, J. G. Tulsa, Okla.
Campbell, W. Thomas Philadelphia, Pa.
Canfield, T. L. Lawton, Okla.
Cann, Kenneth R. Phillipsburg, N. J.
Cantwell, Guy H. Indianapolis, Ind.
†Capaul, R. W. Toledo, Ohio
Cardwell, Paul H. Tulsa, Okla.
Carlberg, Bob L. Ponca City, Okla.
Carlson, Eric G. Philadelphia, Pa.
Carlson, Lawrence A. Rittman, Ohio
Carmichael, C. M., Jr. Toronto, Ontario, Canada
Carmichael, Charles J., Jr. Houston, Texas
Carmichael, Miles Tulsa, Okla.
Carpenter, Dan H. Oklahoma City, Okla.
Carpenter, G. Carey Dallas, Tex.
Carpenter, Gordon D. Port Hueneme, Calif.
Carpenter, Howard B. New York, N. Y.
Carr, Aleck H. Hamilton, Ontario, Canada
Carr, Joseph A. Ridgewood, N. J.
Carr, Myron M. Forest Hills, N. Y.
Carroll, Albert W. Houston, Tex.
Carroll, David R. Houston, Tex.
Carrow, John W., III Wilmington, Del.
Carson, John H. Cleveland, Ohio
Carter Geo. M., Jr. St. Peter, Minn.
Carter, John Jacksonville, Fla.
Carter, Nelson B. Rochester, N. Y.
Casanova, Otis B. Rolling Fork, Miss.
Case, L. C. Tulsa, Okla.
Case, William W. Springfield, Mass.
Casey, John J. Midland, Mich.
†Casey, J. Pat., Jr. Chicago, Ill.
Cash, Wilfrid S. South Gate, Calif.
Caster, Arthur D. Cincinnati, Ohio
Castillo, Ralph A. Dallas, Tex.
Castle, Harry, Jr. Amarillo, Tex.
Cate, Horace V. Toronto, Ontario, Canada
Cates, Charles W. North Vancouver, B. C., Canada
Cates, Walter H. Los Angeles, Calif.
Cathcart, Wallace P. Pittsburgh, Pa.
Caunce, Eric M. P. Windsor Ontario, Canada
Cavallaro, Leo Ferrara, Italy
Cavanagh, W. R. Detroit, Mich.
Cayford, James M. Cleveland, Ohio
†Ceccon, J. B. Chauncey, N. Y.
Chadwick, David H. Anniston, Ala.
Chamberlain, Frank H., Jr. Charlotte, N. C.
Chambers, Alexander R., Jr. Pittsburgh, Pa.
†Chandler, John W. Buffalo, N. Y.
Chaney, L. P. Houston, Tex.
Chapin, Daniel Cleveland, Ohio
†Chapman, E. E. Chicago, Ill.
Chapman, O. Charles Nichols, Fla.
Chapman, Walter H. Phoenix, Ariz.
Chappell, F. Lewis Victoria, B. C., Canada
Charat, Hanoh Dallas, Tex.
Charter, Kenneth F. Milwaukee, Wis.
Chartrand, V. Edward Dallas, Tex.
Chase, Frederick V. Los Angeles, Calif.
Chatelain, John B. Freeport, Tex.
Chatenever, Alfred Norman, Okla.
Chavigny, Neil L. Houston, Tex.
Chenoweth William F. Dayton, Ohio
Cherry, R. Texas City, Tex.
Chesney, Robert B. Benton, La.
Chesnutt, N. P. Dallas, Tex.
Chiasson, Crawford E. West Lake, La.
Childs, Benjamin F. Washington, D. C.
Chisholm, Charles G. Kokomo, Ind.

Chojnowski, Boleslaus S. Great Neck, N. Y.
Christ, Robert E. Pomona, Calif.
Christian, Clarence R. Huntsville, Ala.
Christiansen, Claud B. Montreal, Quebec, Canada
Christie, David E. Dayton, Ohio
Christman, Roger G. Donaldsonville, La.
Chronister, James L. Scott, La.
Chuck, Frank Cabimas Zulia, Venezuela
Church, Laurence T. Springfield, Ill.
Ciborski, John M. Cincinnati, Ohio
Cibula, Henry J. Pittsburgh, Pa.
Clancy, J. J. Deerfield, Ill.
Clapper, Thomas W. Idaho Falls, Idaho
Clark, Albert F. Los Angeles, Calif.
Clark, Claude L. Canton, Ohio
*Clark, Frederick Sharratt, Chatham, Ontario, Canada
Clark, Hezzie Houston, Tex.
†Clark, Joseph B. Tulsa, Okla.
Clark, Manley H. Newport Beach, Calif.
†Clark, O. W. Birmingham, Ala.
Clark, Peter Durham, England
Clarke, B. C. Los Angeles, Calif.
Clarke, Colman W. San Francisco, Calif.
Clarke, Philip A. Edmonton, Alberta, Canada
Clarke, Richard P. Port Arthur, Tex.
Clarke, William Wade Detroit, Mich.
Clarvoe, George W. Manville, N. J.
Clausen, C. C. Dixon, Ill.
Clawson, John A. Culver City, Calif.
†Clay, J. A., Jr. Fort Worth, Tex.
Clayton, Henry M. Memphis, Tenn.
Clayton, William J. Detroit, Mich.
Clemens, John J. Houston, Tex.
Clement Albert J. Morristown, N. J.
Clermont, William L. Newark, N. J.
Cleveland, Theodore K. Berkeley, Calif.
Clifton, W. M. Amarillo, Tex.
Cloninger, Fred M. Tulsa, Okla.
Clough, Philip J. Cambridge, Mass.
Cloyes, William P. Henderson, Nev.
Clutter, James Franklin Salem, Ill.
Coates, Proctor G. Royal Oak, Mich.
Coates, Harry P. Akron, Ohio
Coates, Sanford C. Oklahoma City, Okla.
Cobb, Stephen P. Ashville, N. C.
Cobbett, C. D. New Kensington, Pa.
Coberly, Camden A. Webster Groves, Mo.
Coburn, Seymour K. Chicago, Ill.
Cochran, William C. New Kensington, Pa.
†Coen, I. H. East Pittsburgh Pa.
Coffer, Harold R. Franklin, La.
Coffin, James C. Midland, Mich.
Coffy, Joseph W. Los Angeles, Calif.
Coghill, H. T. Chicago, Ill.
Cohen, Benjamin J. Jersey City, N. J.
Cohen, Ralph Nutley, N. J.
Cohn, Albert A. Jal, N. M.
Coker, Stanley G. Velasco, Tex.
Colburn, Lyle W. Midland, Mich.
Cole, Frank H. New York, N. Y.
Cole, Ralph R. Dallas, Tex.
Coleman, O. K. Lafayette, Ind.
Coleman, W. B. Philadelphia, Pa.
Coleman, W. D. Springfield, Mo.
Coley, Glenn Detroit, Mich.
Collardin, Gerardo Koln-Ehrenfeld, Germany
Collier, David B. Edmonton, Alberta, Canada
Collings, Thomas A. Nanaimo, B. C., Canada
Collins, Dean D. Shreveport, La.
Collins, Harry S. Long Island City, N. Y.
Collins, James H. New Orleans, La.
Collins, J. L. Angleton, Tex.
Collins, John W. Beaumont, Tex.
Collins, Robert Ray Beaumont, Tex.
Collins, Walter F. New York, N. Y.
Collins, William J. Corning, N. Y.
Collopy, Joseph P. Cody, Wyo.
Collopy, William J. Buffalo, N. Y.
Collora, Nicholas A. Baltimore, Md.
Colman, A. R. Montreal, Quebec, Canada
Colyer, David J., Jr. Beverly Hills, Calif.
Comeaux, Roy V. Baytown, Tex.
Comiskey, Patrick T. Jr. Freeport, Tex.
Compton, Kenneth G. Murray Hill, N. J.
Compton, Maryann Cincinnati, Ohio
Conde, Luis Lopez Caracas, Venezuela
Condry, James T. Tulsa, Okla.
Cone, Donald D. Corpus Christi Tex.
Connaughton, John F. Avon, Mass.
†Connell, Jasper S. Wilmington, Calif.
Connelly, D. J. Cleveland, Ohio
Connelly, Lewis B. Houston, Tex.
Connon, William D. Philadelphia, Pa.
Connors, William F. Houston Tex.
Conrad, Howard P. Port Huron, Mich.
Conroy, John H. Houston, Tex.
Contant, Claude Trenton, Mich.
†Converse, E. M. Chicago, Ill.
Conviser, M. B. Kingsport, Tenn.
Cook Conrad J. Houston, Tex.
Cook, Emerson E. Texas City, Tex.
Cook, E. Leon Lake Charles, La.
Cook, Frank E. Washington, D. C.
Cook, George S. Scotia, N. Y.
Cook Lawrence S. Allenport, Pa.
Cook, Leon D., Jr. Wyandotte, Mich.
Cook, William B. Port Arthur, Tex.
Cooley, Herbert M. Tulsa, Okla.
Coons, Ansel L. San Antonio, Tex.
Cooper, Albert H. Baltimore, Md.
†Cooper Herbert J. Hillside, N. J.
Cooper, Wm. C. Cudahy, Wis.
Copeland, Raymond D. Glenwillard, Pa.
Copley, James S. Cleveland, Ohio
Coppersmith, Charles R. Chicago, Ill.
Copson, Harry R. Cranford, N. J.
Corbett R. E. London, Ontario, Canada
†Cordell, P. M. Fort Worth, Tex.
Cordovi, Marcel A. New York, N. Y.
Corfield, Guy Los Angeles, Calif.
Cornell, Drew Lafayette, La.
Cornell, J. P. Dallas, Tex.
Cornet, Israel Berkeley, Calif.
Cornett, W. J. Galena Park, Tex.
Costanzo, Frank E. Pittsburgh, Pa.
Costello, David C., Jr. Bethesda, Md.
Cotton, William J. Milwaukee, Wis.
†Coulson, H. M. Tulsa, Okla.
Coulter, Elmer N. Lake Charles, La.
Coulter, William P. Ardmore, Pa.
Coursey, Ralph W. Oklahoma City, Okla.
†Court, W. F. New York, N. Y.
Couy, C. J. McKeesport, Pa.
†Cowart, B. C. New York, N. Y.
Cowles, James R. Tulsa, Okla.
Cox, Edwin S. Pittsburgh, Pa.
Cox, Gaylord H. Lake Charles, La.
Cox, George C. Charleston, W. Va.
Cox, Gilbert L. Rochester, N. Y.
Cox, Milton K. Pittsburgh, Pa.
Coxhead, Edward P. Oakland, Calif.
†Coyle, T. G. New York, N. Y.
Craig, J. Russell Bethlehem, Pa.
Craighead, William A. Vancouver, B. C., Canada
†Cramer, Anthony H. Detroit, Mich.
Crane, Harold E., Jr. Pittsburgh, Pa.
Crane, James Cincinnati, Ohio
Craver, Albert F. Cleveland, Ohio
Creevy, Joseph A. Newport, Ky.
†Cribley, K. C. Corpus Christi, Tex
Crider, Louis D. Duarte, Calif.
Crobaugh, Albert O. Las Cruces, N. M.
†Crockett, C. L. Roanoke, Va.
Croft, William F. Toronto, Ontario, Canada
Croney, Samuel I. Philadelphia, Pa.
Crosby, William L. New York, N. Y.
Crowe Clifford N. Chicago, Ill.
Crowe, Raymond H. Houston, Tex.
Crowell, J. G. Houston, Tex.
Crowhurst, Frank C. Redwood City, Calif.
Crowley, Edward J. New York, N. Y.
Crumback, A. Lloyd Edmonton, Alberta, Canada
†Cucullu, Lionel J. New Orleans, La.
Culbertson, Alan F. Chicago, Ill.
Culbertson, J. L. Tulsa, Okla.
Cullen, John L. Highland Park, Mich.
Cullen, Thomas G. Orinda, Calif.
Cummer, William F. Beeville, Tex.
Cummings George H. Pasadena, Tex.
Cummings, William P. Spokane, Wash.
Cummins, Frank M. St. Louis, Mo.
Cunningham, George S. Hartford, Conn.
Curdts, E. B. Philadelphia, Pa.
Curley, William R. Clarksburg, W. Va.
Curran, James J. Greenburg, Pa.
Curran, Michael Tulsa, Okla.
†Current, F. L. Oil City, Pa.
Curry, Charles H., Jr. Boston, Mass.
Cushing, Daniel Boston, Mass.
Cushman, George A. Gonzales, Tex.
Cutting, Meritt E. South Barre, Mass.
Cyba, Henry A. Chicago, Ill.

D

†Dabny, Robert L. Houston, Tex.
Daino, Pietro Naples, Italy
Dale, Lawrence H. Berwick, Pa.
Daly, George L. Shreveport, La.
Dalrymple, Robert S. Richland, Wash.
Daligga, Roman E. Birmingham, Mich.
Daniels, Fred A., Jr. Des Moines, Iowa
†Danser, John W. New York, N. Y.
Dantz, Thomas M. New York, N. Y.
Darling, P. E. Texas City, Tex.
Darrin, Marc Baltimore, Md.
Daub, Walter H., Jr. Pittsburgh, Pa.
Daugherty, James G. Philadelphia, Pa.
Davenport, John A. Cincinnati, Ohio
Davidson, John Pt. Edward, Ontario, Canada
Davidson, Robert R. Wilmington, Calif.
Davidson, Wayne K. Montreal, Quebec, Canada
Davie, Frank E. Los Angeles, Calif.
Davies, Alan T. Melbourne, Victoria, Australia
†Davis, Carl R. Butte, Mont.
Davis, Charles T., Jr. Houston, Tex.
Davis, Edward C., Jr. Houston, Tex.
Davis, Edwin G. Haddonfield, N. J.
Davis, F. W. Washington, D. C.
Davis, J. E. Fort Worth, Tex.
Davis, Jack G. Houston, Tex.
Davis, James A. Fort Worth, Tex.
Davis, Leon B. Washington, D. C.
Davis, Leroy J. Glencoe, Ill.
Davis, L. Rex Houston, Tex.
Davis, L. W. Erie, Pa.
Davis, Robert A. Birmingham, Ala.
Davis, Russell L. New York, N. Y.
†Davison, Don W. Wichita, Kan.
Daw, Ronald F. New York, N. Y.
Dawson, R. A. J. Houston, Tex.
Day, Clyde W. Bishop, Tex.
Day, Stephen D. Houston, Tex.
Daymude, John F. Cincinnati, Ohio
deBeers, Franklin M., Jr Glenview, Ill.
De Bruyn, C. A. Lobry Delft, Holland
†De Groot John W. Harrisburg, Pa.
De Laski, Robert D. New York, N. Y.
De Lew, E. Richard San Francisco, Calif.
De Long, William B. Wilmington, Del.
†De Mey, C. F. New York, N. Y.
De Minjer, Clara Henderina Eindhoven, Holland
De Pagter, Henry Milwaukee, Wis.
De Panafieu, R. Paris, France
De Waltoff, Lionel New York, N. Y.
†Deacon, William T., III Big Horn, Wyo.
Deaconson, James N. Wilmington, Del.
Dean, Lyle A. Walnut Creek, Calif.
Dean, Roy O. Emeryville, Calif.
Debevoise, George D. Brooklyn, N. Y.
Decowsky, George N. Philadelphia, Pa.
Deering, F. A. Arkansas City, Kan.
Deering, Robert G. Beaumont, Tex.
Degnan, Thomas F. Wilmington, Del.
Dehaan, Peter C. Des Moines, Iowa
Dehn, George L. C. Dallas, Tex.
†Deichler, J. K. Philadelphia, Pa.
Delcambre, Pierre L. New Iberia, La.
Delong, Raleigh, Jr. Texas City, Tex.
Dempsey, John M., Jr. New York, N. Y.
Denison, Irving A. Washington, D. C.
Dennis, James R. Chattanooga, Tenn.
Dennis, Sidney St. Louis, Mo.
Denoble, Robert J. Santa Ana, Calif.
Denoon, E. M. Miami, Fla.
Depaul, D. J. Pittsburgh, Pa.
Deringer, Wayne A. Milwaukee, Wis.
Derolf, Paul F. Los Angeles, Calif.
Detrick, Charles N. Cleveland, Ohio
Deuber, Carl G. New York, N. Y.
Devoluy, Raymond New York, N. Y.
†Dewar, J. S. Bartlesville, Okla.
Dewar, John S. Toronto, Ontario, Canada
Dewar, William Philadelphia, Pa.
†DeWitt, F. J. Detroit, Mich.
Dewitt, Henry P. Detroit, Mich.
Dewson, Thomas E. Wilmington, Del.
Dey, Charles L. Pittsburgh, Pa.
Dial, D. F., Jr. Houston, Tex.
Diamond, Horace W. Chicago, Ill.
Diamantes, G. Caracas, Venezuela
Dick, Howard C. Westwego, La.
Dickinson, L. R. Plainfield, N. J.
Dickinson, Nancye Ruth Fort Belvoir, Va.
Dickinson, Willis F. Los Angeles, Calif.
Dicktel, Don J. Northbrook, Ill.
Dieck, Herbert W. Mineola, N. Y.
Diehlman, George, New York, N. Y.
†Diemer, R. B. Los Angeles, Calif.
Dietze, Irwin Charles Los Angeles, Calif.
Diggins, Earl R. New Kensington, Pa.
Dillon, Charles P. Texas City, Tex.
Dinges, George Milwaukee, Wis.
Dirks, Richard W. Tuleta, Tex.
Disanto, Bartel J. Salt Lake City, Utah
Dittbrenner, Raymond A. New York, N. Y.
Dittman, William E. Los Angeles, Calif.
Diuguid, John H. Baltimore, Md.
Dix, E. H. Jr. New Kensington, Pa.
Dixon, J. L. Houston, Tex.
Dobbin, W. D. Toronto, Ontario, Canada
Dod, A. Bayard, Jr. Los Angeles, Calif.
Dodd, Mark Point Edward, Ontario, Canada
Dodds, Dale I. Alhambra, Calif.
Dodgen, James E. Hawthorne, Nev.
Dodson, Lee T. Beaumont, Tex.
Doelling, George L. St. Louis, Mo.
Doelling, Robert F. Monaco, Pa.
Doepke, Albert B. Chicago, Ill.
Dolson, Frank E. Jr. University City, Mo.
Donati, Enrico Dalmine, Bergamo, Italy
*Donnellon, John B. Mt. Vernon, N. Y.
Donnelly, James E., Jr. Clairton, Pa.

Donnelly, Joseph B. Philadelphia, Pa.
Donnelly, Patrick R. Lafayette, La.
Donoho, Charles K. Birmingham, Ala.
Donohoe, J. L. Long Branch, N. J.
†Donovan, L. B. New York, N. Y.
Donovan, W. H., Jr. Birmingham, Ala.
Doremus, Gordon L. Houston, Tex.
†Doremus, E. P. Houston, Tex.
Dorr, Frank I., Jr. Houston, Tex.
Dorsey, Joseph S. Los Angeles, Calif.
†Doss, G. K. Longview, Tex.
Dotson, James B. Oakland, Calif.
Doty, Robert O. Oxnard, Calif.
Dougan, Walter R. Great Falls, Mont.
†Dougherty, Wm. J. Sioux City, Iowa
Doughty, S. E. Union, N. J.
Douglas, Burke Midland, Mich.
Douglass, Dave M. Bedford, Ohio
Douglass, Dwight Hartford, Conn.
†Douglass, E. W. Carlsbad, N. M.
Douglass, Harry E. Los Angeles, Calif.
Dowe, Robert J. New Orleans, La.
Dowling, Roy C. Appleton, Wis.
Downing, Dale F. Sacramento, Calif.
Dragics, Earl V. Houston, Tex.
Dragoset, Wm. H. Colonia, N. J.
Drake, Julian D. Yazoo City, Miss.
Dravnieks, Andrew Chicago, Ill.
Dresser, Theodore P., Jr. San Francisco, Calif.
†Drew, A. E. Lufkin, Tex.
†Drewelow, Earl Joplin, Mo.
Dreyman, Edgar W. Brooklyn, N. Y.
Driller, Jack Washington, D. C.
Droby, Henry S. Emeryville, Calif.
Dube, William E. Harvey, La.
Dubois, Carlton H. Buffalo, N. Y.
Dubois, Floyd J. Corpus Christi, Tex.
Duce, R. E. Webster Groves, Mo.
Dudley, William G. Freeport, Tex.
Duesterberg, G. J. Houston, Tex.
Duffner, Gordon H. Chicago, Ill.
Dugan, James A. Cambridge, Mass.
Duggan, Maryann Dallas, Tex.
Duim, Albert R. Los Angeles, Calif.
Dulaney, L. Bowen Houston, Tex.
Dulaney, Robert Woodbury, N. J.
Dunagan, George M. Salem, Ill.
Dunasky, C. F. Cleveland, Ohio
Dunaway, U. C. Clayton, Mo.
Duncan, David L. Chicago, Ill.
Duncan, Norman M. London, Ontario, Canada
Dunn, E. F. Buffalo, N. Y.
Dunn, James W. Detroit, Mich.
Dunne, Norman R. Calgary, Alberta, Canada
Dunning, Sheldon Seattle, Wash.
Durand, Edward A. Chicago, Ill.
Duree, Jack T. Fort Worth, Tex.
Durman, Frederick P. Muncie, Ind.
Durning, A. W. New Orleans, La.
Dutton, W. L. Sarnia, Ontario, Canada
Dwyer, James T. Port Arthur, Tex.
Dwyer, John D., Jr. Wakefield, Mass.
†Dwyer, T. J. Baltimore, Md.
Dyble, Edward Cleveland, Ohio
Dye, Thomas O. Toledo, Ohio
Dykkesten, Wayne Associated, Calif.
Dykman, Milton Rochester, N. Y.

E

Eaches, Albert R. Philadelphia, Pa.
Eager, Russell G. Pavilion, N. Y.
Earl, Robert Jr. Utica, N. Y.
Earnshaw, Charles S. Oakland, Calif.
Easson, Wm. H. Chicago, Ill.
Eastman, Douglas E. West Belmar, N. J.
Ebbs, Edward L. Houston, Tex.
Eberhardt, Ernest T. Hackensack, N. J.
Eberhardt, T. J. Hackensack, N. J.
†Eberle, F. Alliance, Ohio
Ebersole, Larue K. Colorado Springs, Colo.
Ebert, Raymond E. Brenwood, Mo.
†Eckles, W. W. Beaumont, Tex.
Eddison, Clifford Camden, N. J.
Eddy, Levi C. Hinsdale, Ill.
Edgar, Lenville C. Highlands, Tex.
Edminster, James W. Pampa, Tex.
Edmonson, Thomas C. Dallas, Tex.
Edwards, Marvin J. San Diego, Calif.
Edwards, Robert W. San Leandro, Calif.
†Edwards, Wm. H. Houston, Tex.
Effinger, R. T. Riverside, Conn.
Efron, Aaron St. Paul, Minn.
Egan, James F. Fort Worth, Tex.
Eggers, G. Wm. Phillips, Tex.
†Egly, Richard S. Terre Haute, Ind.
Eickhoff, Arnold J. Brooklyn, N. Y.
Eilerts, C. Kenneth Bartlesville, Okla.
Eisenmann, Charles E. New Brunswick, N. J.
Eldred, Norman O. Vicksburg, Mich.
Eldredge, George Emeryville, Calif.
Elkins, Joe G. Opelousas, La.
Elkins, Randell L. Midland, Tex.
Elienz, Fred M. New Iberia, La.
Ellinger, George A. Washington, D. C.
Elliot, Jack H. Los Angeles, Calif.
†Elliott, Robert D. Dallas, Tex.
Elliott, Wm. E. Milwaukee, Wis.
Ellis, Murray P. Painesville, Ohio
Ellis, O. B. Middletown, Ohio
Ellis, William J. Oakland, Calif.
Elliston, H. H. Tulsa, Okla.
Ellwood, Edward E. Houston, Tex.
Emerson, Richard J. El Paso, Tex.
Emery, D. T. John Brownsville, Tex.
Emery, Maurice N. Corpus Christi, Tex.
Enders, Roger S. Long Beach, Calif.
Endicott, L. A. Texas City, Tex.
Englehart, Edwin T., Jr. New Kensington, Pa.
†English, E. Rowland Elizabeth, N. J.
English, Gyme C. New Kensington, Pa.
English, James L. Oak Ridge, Tenn.
Ennis, Herbert E. New York, N. Y.
Enquist, Melvin A. Alhambra, Calif.
Eplett, Albert D. Stratford, Conn.
Epstein, Leonard North Arlington, N. J.
Epstein, Saul Sherman Oaks, Calif.
Erath, Charles A. San Francisco, Calif.
Erben, Alfred R. Dallas, Tex.
Erganian, Alex M. Atlanta, Ga.
Ergul, Necdet F. Tuckahoe, N. Y.
Erich, Earl A. Mertztown, Pa.
Erickson, Bert E. Salt Lake City, Utah
†Erickson, C. A., Jr. Pittsburgh, Pa.
Erickson, E. T. Chicago, Ill.
Ericson, Rudolph C. Hammond, Ind.
Ernst, Jacob W. Milwaukee, Wis.
Estep, Quenton R. Houston, Tex.
Eubanks, Erdie B. Jr. Los Angeles, Calif.
Eutsler, Eugene E. Houston, Tex.
Evans, Charles T., Jr. Delmont, Pa.
Evans, Clair O. New York, N. Y.
Evans, C. W. Shreveport, La.
Evans, David H. Toronto, Ontario, Canada
Evans, Dwight J. Tulsa, Okla.
Evans, Herbert V., Jr. Wilmington, Del.
Evans, Herschel Topeka, Kan.
†Evans, J. M. San Francisco, Calif.
Evans, Robert L., Jr. Houston, Tex.
†Evans, Rulison Wilkes-Barre, Pa.
Everest, Guy N. Passaic, N. J.
Everett, Albert S. San Francisco, Calif.
Everett, O. W. Tulsa, Okla.
†Everett, Ralph H. Lyndhurst, N. J.
Everhart, E. Wayne Spokane, Wash.
†Eves, W. D. Heath New York, N. Y.
Ewing, James H. Long Island City, N. Y.
†Ewing, L. W. Chicago, Ill.
Ewing, Scott P. Tulsa, Okla.
Exum, James P., Jr. Beaumont, Tex.

F

Fair, Cleveland M. Pensacola, Fla.
†Fair, W. F., Jr. Cranford, N. J.
Falck, Sylvan B. Cincinnati, Ohio
Fanett, H. M. Houston, Tex.
†Farber, J. D. Philadelphia, Pa.
Faris, Charles G. East St. Louis, Ill.
Farkas, Ernest C. Cleveland, Ohio
Farkas, Howard New York, N. Y.
Farley, Elden R. Houston, Tex.
Farmer, C. E. Shreveport, La.
Farmer, Sidney C., Jr. Galveston, Tex.
Farrar, Walter B. Kensington, Md.
Farrer, Frank Toronto, Ontario, Canada
Farris, Robert W. Newark, Ohio
Farwell, Milo S. San Francisco, Calif.
Fasig, Paul L. Woodbury, N. J.
Fasold, G. Arthur Cincinnati, Ohio
Faulk, Bill L. Long Beach, Calif.
Featherly, Robert L. Saginaw, Mich.
†Feldman, Karl T. Independence, Kan.
Feldstein, Henry H. Cleveland, Ohio
Feller, Eugene W. F. Pittsburgh, Pa.
Fellows, Claire H. Detroit, Mich.
Fend, William J. St. Louis, Mo.
Fennel, Lawrence, Jr. Portland, Me.
Fenner, Otto H. St. Louis, Mo.
†Fenwick, Dick T. Fort Worth, Tex.
Fergusson, Robert A. Evanston, Ill.
Fernandez, Henry J. Texas City, Tex.
Ferraro, Anthony Woodhaven, N. Y.
Ferree, Ray J. St. Louis, Mo.
Ferrell, William E., Jr. Charlotte, N. C.
Ferrer, Juan Gomez Santurce, Puerto Rico
Ferri, Antonio Milano, Italy
Ferrie, Parmely T. Akron, Ohio
Fetner, Charles J., Jr. Camden, S. C.
†Fetters, Karl L. Youngstown, Ohio
Fiedelman, Howard W. Manistee, Mich.
Fields, Robert E. Dallas, Tex.
Fieser, Arthur Herbert Sparrows Point, Md.
Filkins, Harry L. Kansas City, Mo.
Finch, Lawrence Nelson II New York, N. Y.
Fincher, D. R. Weimar, Tex.
Fincher, Robert K. Memphis, Tenn.
Findl, Eugene Los Angeles, Calif.
Finlay, Robert Windsor, Ontario, Canada
Finlay, Daniel F. Detroit, Mich.
Fink, Frederick W. Columbus, Ohio
Finkelstein, Philip Long Beach, Calif.
Firth, R. Smedley New York, N. Y.
Fischer, Alfred O. Alvin, Tex.
Fischer, H. E. Houston, Tex.
Fischer, Ivan M. Houston, Tex.
Fischer, Paul W. Brea, Calif
Fisher, A. Orman Boston, Mass.
Fisher, B. M. Freeport, Tex.
Fisher, Charles F., Jr. Knoxville, Tenn.
Fisher, Earl E. Glen Olden, Pa.
Fisher, George A., Jr. St. Louis, Mo.
Fisher, Jack L. Houston, Tex.
Fisher, John R., Jr. Dayton, Ohio
Fisher, Leroy E. Holmes, Pa.
Fisher, Max C. Fort Worth, Tex.
Fisher, Ralph A. Houston, Tex.
Fisher, Ralph L. Los Angeles, Calif.
Fiske, C. Walter, Jr. Louisville, Ky.
Fithian, John W. Philadelphia, Pa.
Fitzgerald, Charles L., Jr. Houston, Tex.
Fitzgerald, J. Wilfrid Cleveland, Ohio
Fitzpatrick, Allyn H. Kansas City, Mo.
Flaherty, John T. Chicago, Ill.
†Flanagan, J. C. Houston, Tex.
Flanders, Albert C. Benwood, W. Va.
†Flanders, F. D. Houston, Tex.
Flavell, G. Edward Toledo, Ohio
Fleming, M. C. Bartlesville, Okla.
Fleming, Paul C. Fort Worth, Tex.
Fleming, Thomas J. Santa Monica, Calif.
Flentje, Martin E. Philadelphia, Pa.
Fletcher, Mark D. Chicago, Ill.
Flickinger, L. C. Youngstown, Ohio
Flint, J. W. Wichita, Kan.
Flocke, Frank G. Cleveland, Ohio
Flood, Earl F. Hudson, Ohio
Flor, Loy L. El Cajon, Calif.
Flores, Leopoldo Nettel Tampico, Tamps., Mexico
Flores, Librado Nueva Laredo, Tamps., Mexico
†Flournoy, R. W. Brookfield, Ill.
Flynn, C. K. Sarnia, Ontario, Canada
Flynn, Hugh F. Paramount, Calif.
Foelsch, Henry W. Metuchen, N. J.
Fogelquist, Harold T. Rome, Italy
Foltz, Ross C. Houston, Tex.
Folz, Joseph J. Philadelphia, Pa.
Folzenlogen, M. David Dallas, Tex.
Fonner, Raymond E. Niagara Falls, N. Y.
Fontaine, Edward T. Shreveport, La.
Fontana, M. G. Columbus, Ohio
Footner, H. B. London, England
Forbes, M. C. Houston, Tex.
Ford, Charles D. Palo Alto, Calif.
Forderbrugen, Kevin J. St. Peter, Minn.
Fort, George A. Gary, Ind.
Fossett, William K. Wichita, Kan.
Foster, Albert C. New York, N. Y.
†Foster, J. L. Dallas, Tex.
Fouraker, Robert W. Wilmington, Calif.
Fouts, John M. Buffalo, N. Y.
Fowler, Edward F. Aurora, Ill.
Fox, Arthur R. Berkeley, Calif.
Fox, R. W. Upper Darby, Pa.
Francis, Howard T. Chicago, Ill.
Frank, John A. Cincinnati, Ohio
Frank, Marion E. Houston, Tex.
Frankos, Michael T. Saudi, Arabia
Frasch, H. H. Dallas, Tex.
Fraser, John P. Walnut Creek, Calif.
Fredenburg, Charles W. Chicago, Ill.
Frederickson, Hubert M. Minneapolis, Minn.
Fredley, Kenneth C. Pittsburgh, Pa.
Freeman, C. E. Oakland, Calif.
†Freeman, John R., Jr. Waterbury, Conn.
Freeman, Richard S. Lake Charles, La.
Freeman, William R. Cheltenham, Pa.
French, John D. Montreal, Quebec, Canada
French, John W. Borger, Tex.
Freynick, Henry S. Riverside, N. J.
Friant, Stewart Baltimore, Md.
Frieden, Alexander Milwaukee, Wis.
Friedl, Burt Columbus, Ohio
Friedman, Arthur E. Cleveland, Ohio
Friedman, Charles Long Island City, N. Y.
†Friend, W. Z. New York, N. Y.
Frink, Joe Miami, Fla.
Frisius, Edward N. Santa Fe Springs, Calif.
Friton, Edwin E. St Louis, Mo.
Fritts, Charles J. Dallas, Tex.
Fritts, Harry W. New Kensington, Pa.
Friz, Nelson New York, N. Y.
Frizell, Glenn H. Shreveport, La.
Frogner, Willard B. New York, N. Y.
†Frye, Seymour Charles Bethlehem, Pa.
Frykholm, Oliver C. Kansas City, Mo.
Fuchs, Fritz E. Houston, Tex.
Fugazzi, John F. Denver, Colo.
Fugle, Forrest F. San Marino, Calif.
Fujimuro, Masuzo Tokyo, Japan
Fujiwara, Tadayoshi Tokyo, Japan
Fulghum, Clark San Francisco, Calif.
Fuller, Carl T. Houston, Tex.
Fuller, Nelson M. Batavia, N. Y
Fullerton, F. W. Oklahoma City, Okla.
Fullman, James B. Stamford, Conn.
Furgason, Clyde A. Cudahy, Wis.
Furth, M. A. Nederland, Tex.

G

Gackenbach, Russell E. Bound Brook, N. J.
Gaido, S. J. Houston, Tex.
Gaiennie, Ernest S., Jr. New Orleans, La.
Gaines, Earl B. New Orleans, La.
Gaines, Paul Barrancabermeja, Colombia, S.A.

Gallagher, John S. ..... Los Angeles, Calif.
Gallup, Dudley D. ..... Bala Cynwyd, Pa.
Gally, Sidney K. Pasadena, Calif.
†Gamble, Chas. B., Jr. ..... Birmingham, Ala.
†Gamble, George P. ..... St. Louis, Mo.
Gambow, Lewis J. ..... Ellwood City, Pa.
Gammache, Robert L. ..... Bedford, Va.
Gannon, John V. ..... Pampa, Tex.
Gans, Daniel, Jr. ..... Boston, Mass
Gansler, William George ..... Toronto, Ontario, Canada
Garber, Samuel Washington, D. C.
Garber, William F. Venice, Calif.
Garcia, Antonio Blanco ..... Caracas, Venezuela
†Garcia, Luis ..... Wayne, Mich.
Gard, Charles M. ..... Worthington, Ohio.
Gardiner, Peter ..... Houston, Tex.
Gardner, Bryant H. ..... Springfield, Mass.
Gardner, Franklin T. ..... Tulsa, Okla.
Gardner, G. Douglas ..... Louisiana, Mo.
Gardner, Karl A. Massillon, Ohio
Garlette, William A., Jr. ..... Nitro, W. Va.
Garlock, Neil B. ..... Joplin, Mo.
Garner, Cordelle L. Houston, Tex.
Garrett, Fred A. ..... Dallas, Tex.
Garrett, G. H. ..... Denver, Colo.
Garrett, William W. ..... Birmingham, Ala.
Garrison, V. L. ..... Paterson, N. J.
Gartner, Fred W., Jr. ..... Houston, Tex.
Garvin, William H. Dallas, Tex.
Gaston, Don Los Angeles, Calif.
Gattenmeyer, John L. ..... Calgary, Alberta, Canada
†Gay, John M. ..... Houston, Tex.
Geary, Arthur L. Weirton, W. Va.
Geddes, Charles Albert, Jr. ..... Houston, Tex.
Gee, Edwin A. ..... Newport, Del.
Geerlings, H. G. ..... Amsterdam, Netherlands
†Gegner, Paul J. Barberton, Ohio
†Gehres, H. A. ..... Mount Vernon, Ohio
Geissinger, Richard M. ..... Milwaukee, Wis.
Geist, Norman S. ..... East St. Louis, Mo.
Gelfer, Daniel H. Southgate, Calif.
Georgi, Charles D. St. Louis, Mo.
Gerben, Max ..... Long Island City, N. Y.
German, Alfred New York, N. Y.
German, John P. ..... Miami, Fla.
Gernert, Marvin L. ..... Kingsport, Tenn.
Gerow, Robert C. ..... Wilmington, Del.
Gerrard, John S. ..... Ahmadi, Kumwaiit, Persian Gulf
Gersch, Leo P. Santa Ana, Calif.
Gerson, Frederick T. ..... Toronto, Ontario, Canada
Gettys, Wilbur H. ..... Bartlesville, Okla.
Gibbon, Anthony ..... Tulsa, Okla.
Gibson, Joseph W. ..... San Antonio, Tex.
Gibson, Sidney A. Fairfield, Ala.
Giddings, E. W. G. ..... Montreal, Quebec, Canada
†Gieser, Ralph Whittier, Calif.
Gifford, Edmund W. ..... Milwaukee, Wis.
Gilbert, Harry E., Jr. ..... Springdale, Pa.
Gillan, Howard J. Rochester, N. Y.
Gilliams, Francis B. ..... Philadelphia, Pa.
Gillman, Jonas H. St. Paul, Minn.
Gilmore, Ernest A., Jr. ..... Wichita, Kan.
Givens, Allen T. ..... Monroe, La.
†Glasgow, Clarence O. ..... Tulsa, Okla.
†Glasgow, Robert A. ..... Los Angeles, Calif.
†Glass D. C. ..... Chicago, Ill.
Glassgold, I. Leon ..... Baltimore, Md.
Gleason, Alvin T. Shreveport, La.
Glenn, Denis ..... Beaumont, Tex.
Glenny, C. A. ..... Fort Erie, Manitoba, Canada
Gleser, Sol M. ..... St. Louis, Mo.
Glidden, William E. Pitman, N. J.
Glover, Manson ..... Malden, Mass.
Glover, Sheldon W. ..... Los Angeles, Calif.
†Godard, H. P. ..... Kingston, Ontario, Canada
Godfrey, John W. Lockport, N. Y.
Godfrey, William Kerr ..... Los Angeles, Calif.
Godshalk, James B. ..... Philadelphia, Pa.
Godshall, J. Byron ..... Easton, Pa.
†Goebel, Eugene S. ..... Chicago, Ill.
Goen, Paul S. ..... Los Angeles, Calif.
Goit, Laurance E. ..... Los Angeles, Calif.
†Goldsby, Fred L. ..... New York, N. Y.
Golub, Lillian Lena ..... Jersey City, N. J.
†Goodall, R. A. ..... Ogallala, Neb.
Goodell, Robert E. Augusta, Kan.
Goodman, E. E. Granite City, Ill.
Goodman, Winkler W. ..... Cincinnati, Ohio
Goodnight, Robert H. ..... Tulsa, Okla.
Goodno, Charles W. ..... Bakersfield, Calif.
Goodrich, Abijah V. ..... Long Beach, Calif.
Goodrich, C. R. San Antonio, Tex.
Goodson, Loyd ..... Shawnee, Okla.
†Goodwin, Carlton L. ..... Portland, Me.
Goodwin, James M. ..... Lancaster, Ohio
Gorden, C. D. ..... Katy, Tex.
Gordon, Douglas H. ..... New York, N. Y.
Gordon, John J. ..... Buffalo, N. Y.
Gordon, Joyce A. Whittier, Calif.
Gordon, Maurice B. ..... Baltimore, Md.
Gorman, L. J. ..... Brooklyn, N. Y.
Gorr, Walter W. ..... Pittsburgh, Pa.
Gosnell, Everett C. ..... Cleveland, Ohio
Gosnell, Kenneth R. ..... Charleston, W. Va.
†Gotsch, L. P. ..... Maywood, Ill.
Gottliebsen, Lenius H. ..... Louisville, Ky.
Goudielock, W. B. O'Brien ..... New York, N. Y.
Gould, Earl D. ..... Tulsa, Okla.
Gow, H. G. ..... Sheffield, Great Britain
Gow, James T. ..... Portland, Ore.
Gowans, Louis L. Honolulu, T. H.
Graber, Walds E. ..... Liberal, Kan.
Grady, Jack L. Kansas City, Mo.
Graeser, Henry J. Dallas, Tex.
†Graham, H. W. ..... Pittsburgh, Pa.
Graham, William J. ..... Toronto, Ontario, Canada
Grandi, Alberto ..... Milano, Italy
Grant, Robert L. ..... Boston, Mass.
Grassman, Herbert S. ..... Oak Park, Ill.
Graves, Colburn R. ..... Garden City, N. Y.
Graves, J. H. ..... Joinerville, Tex.
Graves, John W. Shreveport, La.
Graves, Russell L. ..... Los Angeles, Calif.
†Gray, A. E. ..... Allison Park, Pa.
Gray, Harold W., Jr. Odessa, Tex.
Gray, R. M. ..... Long Beach, Calif.
Greathouse, Glenn A. ..... Washington, D. C.
Grebe, H. A. ..... Houston, Tex.
Grebe, John J. ..... Midland, Mich.
†Greber, A. C. Cincinnati, Ohio
Grebinar, Herbert L. ..... New York, N. Y.
Grebstad, Enest H. ..... Los Angeles, Calif.
Greco, Edward C. ..... Shreveport, La.
Green, Donald R. ..... Kalamazoo, Mich.
†Green, E. F. Los Angeles, Calif.
Green, Jerome ..... Chicago, Ill.
†Green, W. A. Little Rock, Ark.
Green, Walter ..... Norwalk, Calif.
Green, Willis G. ..... Los Angeles, Calif.
Greene, John F., Jr. Barber, N. J.
Greenwell, Howard E. ..... Dallas, Tex.
Greenwood, W. Brian ..... Nanaimo, B. C., Canada
Greer, Norman E. Houston, Tex.
Gregg, Harris T. ..... Houston, Tex.
Gregory, Milton W. Toledo, Ohio
†Gregory, R. P. ..... Houston, Tex.
Gresimer, Robert E. ..... Jacksonville, Fla.
Grether, Fred ..... Van Nuys, Calif.
Grey, John R. ..... Vancouver, B. C., Canada
Gribble, Charles G., Jr. ..... Houston, Tex.
Griffin, Everett M. ..... Birmingham, Ala.
Griffin, Justin O. ..... Shreveport, La.
Griffith, Darrel F. Victoria, Tex.
Griffith, Dean O. ..... Houston, Tex.
Griffith, T. Ed ..... Houston, Tex.
Griffiths, Charles W. ..... Camden, N. J.
Griggs, Henry P. ..... Silver Springs, Md.
Griswold, T. N. Ponca City, Okla.
Grizzard, Eugene H. ..... Los Angeles, Calif.
Grogg, Phillip A. St. Louis, Mo.
Grondal, Bror J. Belmont, Mass.
Groninger, Clark R. Austin, Tex.
Gross, A. F. ..... St. Louis, Mo.
Gross, Lewis Corpus Christi, Tex.
Grounds, Leo R. ..... Mexico, D. F.
Groves, Ken D. ..... Chicago, Ill.
Gruber, K. A. ..... Long Island City, N. Y.
†Gruca, E. P. ..... Hammond, Ind.
Guba, Frank A. ..... Union, N. J.
Guenther, Paul R. Buffalo, N. Y.
Guernsey, Richard L. ..... Fort Worth, Tex.
Guerry, William A. ..... Little Silver, N. J.
Guild, Bernard R. Carlsbad, N. M.
Guinn, C. F. ..... Houston, Tex.
Guinther, Paul J. Jr. ..... Detroit, Mich.
Gumm, Howard W. Houston, Tex.
Gumm, Warren G. Houston, Tex.
Gunter, Edgar J. ..... New York, N. Y.
Gurney, William B. ..... Baton Rouge, La.
Guthrie, John M. ..... Philadelphia, Pa.
Guttenplan, Jack D. ..... Highland Park, Mich.

H

†Haas, C. A. ..... Houston, Tex.
Haas, D. Marshall Baytown, Tex.
Haas, Nields B. ..... Coraopolis, Pa.
†Haas, W. B. ..... Omaha, Neb.
Haase, Harold F. Milwaukee, Wis.
Hack, Carl H. ..... Brooklyn, N. Y.
Hackerman, Norman Austin, Tex.
Hackett, Albert Harold ..... Caracas, Venezuela, S. A.
Hackett, John S. Brooklyn, N. Y.
†Hackney, R. Peele ..... Richmond, Va.
Haddad, Ibrahim Sami ..... Beirut, Lebanon
Hadley, Raymond F. ..... Philadelphia, Pa.
Haering, Vera W. ..... San Antonio, Tex.
Hafer, Richard F. Louisville, Ky.
Hagemeier, Charles E. ..... Houston, Tex.
Hager, Frederick ..... Elmira, Ontario, Canada
Hager, Karl F. ..... Huntsville, Ala.
Hagerman, Charles W. ..... Oreland, Pa.
Hagerman, John R. ..... Chicago, Ill.
Hagius, Karl S. ..... Colorado Springs, Colo.
Hahn, A. H. ..... Tulsa, Okla.
Haile, Edward L. Texas City, Tex.
Halbig, John J. Middletown, Ohio
†Hale, Robert L., Jr. ..... Lake Charles, La.
Hale, William L. Brooklyn, N. Y.
Haley, Herbert P. ..... Albany, Ga.
Halff, Albert H. ..... Dallas, Tex.
Hall, Elwin B. Los Angeles, Calif.
Hall, F. Allen Idaho Falls, Idaho
Hall, George D. ..... Houston, Tex.
Hall, Kenneth G. Elizabeth, N. J.
Hall, Larry Cully ..... Urbana, Ill.
Hall, Marvin F. ..... New York, N. Y.
Hall, Nathaniel Brooklyn, N. Y.
Hall, R. E. ..... Brea, Calif.
Hall, Vincent J. ..... Chicago, Ill.
Hall, Wilfred N. ..... Montreal, Quebec, Canada
Hall, William A. Philadelphia, Pa.
Hallden, John T. Rockford, Ill.
Halloran, William D. ..... Houston, Tex.
Halsell, Hampton L. ..... Fayetteville, Ark.
Haltom, Forrest E. ..... Port Arthur, Tex.
Haltom, J. Myrl ..... Dallas, Tex.
Hamann, Charles E. ..... West Lynn, Mass.
Hamel, Richard W., Jr. ..... Richmond, Va.
Hamer, Fred W. E. ..... Toronto, Ontario, Canada
Hamilton-Smith, A. Kent, England
Hamilton, Archer B. ..... Hartford, Conn.
Hamilton, Hugh L. Ardmore, Pa.
Hamilton, J. S. ..... New Kensington, Pa.
Hamlin, Arthur W. ..... New York, N. Y.
Hammett, Henry Louis, Jr. ..... New Orleans, La.
Hammond, Milton B. ..... Edgeworth Sewickley, Pa.
Hamstead, A. C. ..... South Charleston, W. Va.
Hancock, Charles W. Tulsa, Okla.
Hancock, John ..... Boston, Mass.
Hanes, Henry W. ..... Jacksonville, Tex.

†Haney, Charles E. Portland, Ore.
Hansen, Arnold W. ..... Milwaukee, Wis.
Hansen, Edward M. ..... Santa Monica, Calif.
Hansen, Eugene R. Houston, Tex.
Hansen, Tolbert L. ..... Walnut Creek, Calif.
Hanson, Harry R. Houston, Tex.
Hanson, Joseph Harry ..... Long Beach, Calif.
Hanson, Melvin A. ..... Bloomington, Ill.
Happ, Charles R. ..... Port Arthur, Tex.
†Harbaugh, R. L. ..... East Chicago, Ind.
Harbison, Dixon T. ..... Fort Worth, Tex.
Hardaway, Rex. L. ..... Corpus Christi, Tex.
Harden, Gail D. ..... East Chicago, Ind.
Harder, Robert G. Pittsburgh, Pa.
Hardman, James T. Tulsa, Okla.
Hardy, Ivan C. ..... Ottawa, Ontario, Canada
Hargroder, A. D. ..... Lake Charles, La.
Harker, Thomas W. ..... Morton Grove, Ill.
Harlan, John L. ..... Houston, Tex.
Harley, Henry G. St. Louis, Mo.
Harman, George Robert ..... Pittsburgh, Pa.
Harmon, Kenneth H. ..... Birmingham, Ala.
Harmon, Richard E. ..... Washington, D. C.
Harnsberger, A. E. Chicago, Ill.
Harper, George M., Jr. ..... Abbeville, La.
Harple, Warren W. ..... Brackenridge, Pa.
†Harris, Jack W. ..... Houston, Tex.
Harris, John J. ..... Dallas, Tex.
Harris, Lester K. Bethlehem, Pa.
Harris, Lucian F. Longview, Tex.
Harris, Philemon G. ..... Los Angeles, Calif.
Harrison, Gordon D. ..... Knoxville, Tenn.
Harrison, James R. Newark, Ohio
Hart, James L. Bartlesville, Okla.
Hart, M. B. ..... Brookfield, Ill.
Hart, Porter ..... Freeport, Tex.
Hartkemeier, Leonard W. ..... Golden, Colo.
Hartman, H. F. ..... Baytown, Tex.
Hartwell, Richard R. ..... Maywood, Ill.
Hartwick, Otto J. ..... Houston, Tex.
Hartz, Marvin E. Milwaukee, Wis.
†Harvey, C. C. Baton Rouge, La.
Harvey, Frank H. ..... Baton Rouge, La.
Harvick, David W. St. Louis, Mo.
Harwood, Julius J. ..... Washington, D. C.
†Hasenritter, Delmar ..... St. Louis, Mo.
Haskins, Frank D. Flint, Mich.
Hatch, George B. Pittsburgh, Pa.
Hatch, J. Hadley ..... Los Angeles, Calif.
Hatchett, V. W. ..... Augusta, Kan.
Hatfield, G. A. ..... Torrance, Calif.
Hatfield, Homer F. Allentown, Pa.
Hausman, John C. Harrisburg, Pa.
Hawke, David L. Brooklyn, N. Y.
Haworth, Burton C. ..... Wilmington, Del.
Hayes, William B. ..... Chauncey, N. Y.
Hayner, Donald L. ..... Milwaukee, Wis.
Haynes, Harold J. ..... New Orleans, La.
Hays, L. R. ..... Lake Charles, La.
Hayward, Harold N. Urbana, Ill.
Healey, Edward Lewis ..... Sayville, N. Y.
Heath, John R. Cleveland, Ohio
Heathfield, Patrick E. ..... Sheffield, Great Britain
Heatley, David J. Houston, Tex.
Hecht, Leon M., Jr. ..... Stamford, Conn.
Hecker, Carl R. Elizabeth, N. J.
Hedborg, Carl E. ..... Brea, Calif.
Hedges, Eugene B. Saginaw, Mich.
Hedrick, H. M. Long Beach, Calif.
Heffernan, Thomas J. ..... Toronto, Ontario, Canada
Heger, J. J. ..... Pittsburgh, Pa.
Heidebrecht, Allen R. ..... Kansas City, Mo.
Heideman, William A. ..... East St. Louis, Ill.
Heil, Carl E. ..... Cleveland, Ohio
Heinemann, Gustave ..... Corpus Christi, Tex.
Heinen, Lawrence E. ..... Houston, Tex.
Heinzelman, Edward, Jr. ..... Palisades Park, N. J.
Heinzerling, Robert F. ..... Glen Ridge, N. J.

Heiss, Franklin S. D. Philadelphia, Pa.
Heitman, Talmage M., Jr. Houston, Tex.
†Helmbrecht, A. J. New York, N. Y.
Helmrath, Norman K. Chicago A, Ill.
Helms, Robert F. Lafayette, La.
Hempsall, Leslie C. Vancouver, B. C., Canada
Hencher, Harry A. Montreal, Quebec, Canada
Henderson, E. L. Shreveport, La.
Henderson, J. G. South Charleston, W. Va.
Henderson, Joseph A. Pensacola, Fla.
Henderson, Mervin W. Springfield, Mo.
Henderson, Oliver Cleveland, Ohio
Henderson, Walter A. New York, N. Y.
Henderson, William W. Pensacola, Fla.
Hendrick, John O., Jr. Lafayette, La.
Hendricks, L. Hartley Wilmington, Calif.
†Hendrickson, David Oakland, Calif.
Henry, Ernest L. Houston, Tex.
Henry, R. E. Longview, Tex.
Herberg, William F., Jr. Houston, Tex.
Herbst, Irene A. Milwaukee, Wis.
†Herringshaw, D. E. Jackson, Mich.
Herrmann, Hans New York, N. Y.
Herrmann, G. Russell New York, N. Y.
Hersey, E. Peter Montreal, Quebec, Canada
Herstein, Frederick E. Plainfield, N. J.
Hertel, Wallace E. Lake Geneva, Wis.
Herzler, Ralph E., Jr. Chicago, Ill.
Herzog, Francis J. Monsanto, Ill.
Herzog, Max A. Springfield, Mo.
Heskett, David M. Tucson, Ariz.
Hess, Albert W. Camden, N. J.
Hess, Fred E. Fort Worth, Tex.
†Hess, W. T. New Orleans, La.
Hess, William L. Lincolnwood, Ill.
Hetherington, John A. Via Bahrein, Persian Gulf
Hetzel, Harry T. Blawnox, Pa.
Heverly, L. F. Kansas City, Kan.
Hewes, Frank W. Edmonton, Alberta, Canada
Hewitt, Harry N. Montreal, Quebec, Canada
Hewitt, Ralph W., Jr. Plattsburg, N. Y.
Hibbs, Don B. Kansas City, Mo.
Hibler, Howard M. Fort Worth, Tex.
Hibler, M. Y. Austin, Tex.
Hickethier, Carlos F. Buenos Aires, Argentina
Hicks, Charles P. New York, N. Y.
Hieronymus, Frantz M. Tulsa, Okla.
Hiers, George O. Baldwin, N. Y.
Higburg, Wm. Indianapolis, Ind.
Higgins, Edward J. Westfield, N. J.
Higgins, J. D., Jr. Fort Worth, Tex.
Higgins, R. I. Washington, D. C.
Higgins, Waldo W. Kankakee, Ill.
Higgins, William F. Manchester, England
Hilbert, Edwin W. New York, N. Y.
Hiley, R. B. Harrison, N. J.
Hill, David L. Detroit, Mich.
Hill, George R. Salt Lake City, Utah
†Hill, Leonard C. Hastings, Neb.
Hill, Preston W. Long Beach, Calif.
Hill, Roy W. Fort Belvoir, Va.
Hill, Wallace T. Owatonna, Minn.
Hiltner, Luther G. Los Angeles, Calif.
Hilton, Robert W. Plainfield, N. J.
Himel, George B. Los Angeles, Calif.
Himmler, Alden C. Hollywood, Md.
Hinchman, William H. D. Detroit, Mich.
Hinckley, Arthur T. Niagara Falls, N. Y.
Hind, Harry L. Boston, Mass.
Hinkle, George S., Jr. Houston, Tex.
Hinkle, W. H. Portland, Ore.
Hirdler, F. Carl, Jr. Los Angeles, Calif.
Hirshfeld, James F. Detroit, Mich.
Hiskey, C. G. Houston, Tex.
Histed, Ralph T. Oak Lawn, Ill.
Hoagland, Stanley L. Chicago, Ill.
Hobbs, Raymond Leon Wilmington, Calif.
†Hobbs, W. H. St. Louis, Mo.
Hocker, C. Richard Columbus, Ohio
Hodson, Fred W. Corpus Christi, Tex.
Hoeveler, J. H., Jr. New York, N. Y.
Hoffer, George Victoria, Tex.
Hoffman, Thomas L. Idaho Falls, Idaho
Hogan, Robert E. Springfield, Mo.
Hoiberg, Arnold J. El Dorado, Ark.
Holcomb, William D. Chicago, Ill.
†Holcombe, Tom L. Shreveport, La.
Holefka, Theodore Houston, Tex.
Holland, Charles J., Jr. Dallas, Tex.
Holler, Homer D. Chevy Chase, Md.
Holloway, J. A. Edna, Tex.
Holm, Emil G. Houston, Tex.
Holman, George Gordon, Toronto, Ontario, Canada
†Holmberg, Emil G. Linden, N. J.
Holmberg, M. E. Houston, Tex.
Holmes, Alvin W. Muncie, Ind.
Holmes, Laird E. Robinson, Ill.
Holsinger, Fred J. Argo, Ill.
Holmsten, Willard E. Chicago, Ill.
Holsteyn, Derk Houston, Tex.
Holt, James B. Dallas, Tex.
Holtman, Clemens W. Louisville, Ky.
Holzworth, Monta L. North Augusta, S. C.
†Honkala, H. E. Decatur, Ala.
Honovich, Joseph F., Jr. Shreveport, La.
Hookanson, Kenneth G. Morton Grove, Ill.
Hookway, William C., Jr. Hillside, N. J.
Hooper, Raymond R. New York, N. Y.
Hoover, Morgan M. New York, N. Y.
Hopkins, Arthur James Melbourne, C. I. Vic., Australia
Hopkins, James L. Columbus, Ohio
Hopkins, W. H. Houston, Texas
†Hopper, E. W. Pittsburgh, Pa.
Hopper, Ralph V. Baton Rouge, La.
†Hopson, R. P. Tulsa, Okla.
Hopwood, William A. Odessa, Tex.
†Horne, A. N. Toronto, Ontario, Canada
†Horner, William L. Tulsa, Okla.
Horst, Ralph L., Jr. New Kensington, Pa.
†Horstman, W. G. Atlanta, Ga.
Hort, Percy Philadelphia, Pa.
Horton, James B. Bethlehem, Pa.
Horton, John Leroy Natchez, Miss.
Horton, Roy Tulsa, Okla.
Horvath, Louis Cleveland, Ohio
Hose, Alfred G. Cleveland, Ohio
Hosford, Harry W. Cleveland, Ohio
Hoster, T. G. Baltimore, Md.
Howald, Thomas S. Euclid, Ohio
Howard, Harry W. Union, N. J.
Howard, Owen G. Toledo, Ohio
Howell, Irvin N., Jr. Columbia, S. C.
Howell, John C. Maplewood, N. J.
Howell, R. P. San Francisco, Calif.
Howson, Oliver B. London, Ontario, Canada
Hoxeng, Raymond B. Pittsburgh, Pa.
*Hoxie, Earle C. Dana, Ind.
†Hoyt, W. B. New York, N. Y.
Hubard, Stephen S. Baltimore, Md.
*Hubble, Richard J. College Station, Tex.
Huckleberry, S. A. Corpus Christi, Tex.
Huddleston, Charles E., Jr. Beaumont, Tex.
Huddleston, Wm. E. Bartlesville, Okla.
Hudock, George W. Park Forest, Ill.
Hudson, M. B. Zionsville, Ind.
Hueseman, Robert L. Houston, Tex.
Huff, Robert W., Jr. Bellaire, Tex.
Huggenberger, Otto R. Montreal, Quebec, Canada
Hughes, Charles F. Port Arthur, Tex.
Hughes, David K. Houston, Tex.
Hughes, H. D. Dallas, Tex.
Hughes, Henry M. Tulsa, Okla.
Hughes, Homer L. Farmington, Mo.
Hugo, L. A. Bartlesville, Okla.
Huitt, Troy L. Philadelphia, Pa.
Hulcy, Louis B. Dallas, Tex.
Hull, George C., Jr. Newark, N. J.
Hull, Joseph W. Rochester, N. Y.
Hull, Tennyson J., III Houston, Tex.
Humber, Joe B. Texas City, Tex.
†Humble, H. A. Midland, Mich.
Humke, Roger K. Detroit, Mich.
Hummon, C. Gerald Kansas City, Mo.
Humphries, Thomas S., Jr. New Kensington, Pa.
Hunt, A. J. Odessa, Tex.
Hunt, Bill E. Decatur, Ill.
Hunter, Felix A. Abilene, Tex.
Hunter, John C. Wilmington, Calif.
Hunter, J. N., Jr. Tulsa, Okla.
Hunter, Ralph M. Midland, Mich.
Huntley, Harold R. New York, N. Y.
Hur, J. James Philadelphia, Pa.
Hurley, E. T. Montreal, Quebec, Canada
Hurst, Ralph Jackson, Miss.
Hurtado, J. R. Caracas, Venezuela, S. A.
Hurtgen, Archibald Louisville, Ky
Huscher, Joseph L. Bedford, Ohio
Huseby, Robert A. Milwaukee, Wis.
Husock, Bernard Cleveland, Ohio
*Hustead, B. G. Kilgore, Tex.
Huston, Kenneth M. Baltimore, Md.
†Hutchcraft, D. K. Olean, N. Y.
Hutchinson, Carroll O. Chicago, Ill.
Hutchinson, Gilbert E. Midland, Pa.
Hutchison, William A. Independence, Kan.
Huth, Eugene G. Cleveland, Ohio
Hutzler, George J. Philadelphia, Pa.
Hyde, Marshall Port Huron, Mich.
Hynes, Harold K. Houston, Tex.
Hyslop, Heard W. Hamilton, Ontario, Canada
Hyypia, Jorma Glennville, Conn.

I

Imhoff, Carroll E. Milwaukee, Wis.
Ince, Strachan Toronto, Ontario, Canada
Ing, Clayton V., Jr. Fort Worth, Tex.
Ingham, Herbert S. Long Island City, N. Y.
Ingram, Sidney M. Shreveport, La.
Irish, Lynton B. Shreveport, La.
Irvin, James A. Shreveport, La.
Irving, Ralph Houston, Tex.
Irwin, C. A. Brownsville, Tex.
Isaacks, Albert N. Independence, Mo.
†Isherwood, J. H. Port Allegany, Pa.
Isles, Frederick W. Linden, N. J.
Israel, Cedric Los Angeles, Calif.
Ivanso, Eugene V. Detroit, Mich.

J

†Jack, V. K. Chicago, Ill.
Jackson, C. M. Louisville, Ky.
Jackson, J. Harry Columbus, Ohio
Jackson, James O. Pittsburgh, Pa.
†Jackson, Maynard H. Tulsa, Okla.
Jackson, Robert M. Rochester, N. Y.
Jackson, Robert O. Salem, Ind.
Jackson, Russell Phoenix, Ariz.
Jackson, Willis E. Toledo, Ohio
Jacobek, Warren G. Forest Park, Ill.
Jacobs, Eugene F. Linwood, Calif.
Jacobson, Clarence M. Philadelphia, Pa.
Jacobson, John Walter Chicago, Ill
Jacobson, Murray Watertown, Mass.
†Jaeger, John G. Brooklyn, N. Y.
Jahnz, Hugo R. C., Jr. Charleston, S. C.
James, Evan J. Hawthorne, Calif.
James, H. E. Jackson, Miss.
James, Jay R. Tulsa, Okla.
James, Paul W. Syracuse, N. Y.
Janke, Peter L. Elmwood Park, Ill.
Janota, Rudolph B. Chicago, Ill.
Janssen, Walter S. Texas City, Tex.
Janssens, Emile-Valerie Botanique, Brussels, Belgium
Janssens, W. D. Drexel Hill, Pa.
Jared, John B., Jr. Houston, Tex.
Jasek, Albert W. Houston, Tex.
Jay, Lester L. New Iberia, La.
Jay, Webb New Orleans, La.
Jednacz, John E. Philadelphia, Pa.
Jeffares, George M. Atlanta, Ga.
Jehu, Llewellyn, Jr. Lachine, Quebec, Can.
Jekot, Chester M. Chicago, Ill.
Jelen, Frederic C. Syracuse, N. Y.
Jelinek, Frank R. Port Neches, Tex.
Jenkins, Clark L. Houston, Tex.
†Jenkins, Vance N. Brea, Calif.
Jennings, Carl H. Fort Worth, Tex.
Jennings, John W. Nuevo, Rosita, Coah., Mex.
Jensen, Claude H. Glassport, Pa.
Jensen, O. L. Bellwood, Ill.
Jenss, Alfred D. Cincinnati, Ohio
Jessen, Frank W. Austin, Tex.
Jessen, Oliver C. Los Angeles, Calif.
Jewell, James G. Pittsburgh, Pa.
Joecks, Adolph K. New York, N. Y.
Johannes, E. Gent St. Louis, Mo.
Johnquest, Harry M. Waterbury, Conn.
Johns, Donald H. St. Louis, Mo.
Johnsen, Walter Staten Island, N. Y.
Johnson, Carl R. New York, N. Y.
Johnson, Carl V. Philadelphia, Pa.
Johnson, Clement O. Jacksonville, Fla.
Johnson, Dewey W. Chicago, Ill.
Johnson, Earl A. N. Shelton, Wash.
Johnson, Elmer A. Lincoln, Calif.
Johnson, Ernest B. Tulsa, Okla.
†Johnson, Felix M. Oklahoma City, Okla.
Johnson, Gerald M. Fort Worth, Tex.
Johnson, Herbert S. Shawinigan Falls, Que., Can.
Johnson, J. F., Jr. Zionsville, Ind.
Johnson, R. K. New York, N. Y.
Johnson, Robert L. Jackson, Mich.
Johnson, Robert T. Freeport, Tex.
Johnson, T. E. Beloit, Wis.
Johnson, W. A. Melbourne, C.1, Vic., Australia
Johnson, Walter C. Columbus, Ohio
Johnson, Wayne A. Houston, Tex.
Johnson, William C. Kalamazoo, Mich.
Johnson, Wm. W. Port Arthur, Tex.
Johnston, Donald P. Carlsbad, Calif.
Johnston, Howard E. New York, N. Y.
Johnston, J. Flynn Atlanta, Ga.
Johnston, John E. Tulsa, Okla.
Johnston, Thomas A., Jr. Wichita, Kan.
Jones, Charles C. Philadelphia, Pa.
Jones, Charles H. Bogota, Colombia, S. A.
Jones, Darrell M. Corpus Christi, Tex.
Jones, David C. Calgary, Alberta, Canada
Jones, David T. North Hollywood, Calif.
Jones, E. N. Pettus, Tex.
Jones, Elmer H. Los Angeles, Calif.
Jones, Everett P. Houston, Tex.
†Jones, G. C. Jackson, Miss.
Jones, Gaston V. Shreveport, La.
Jones, George T. Montreal, Quebec, Canada
Jones, Harold Morgan Winnipeg, Manitoba, Canada
Jones, Harry L. Los Angeles, Calif.
Jones, Henry P. Salt Lake City, Utah
Jones, J. Raymond Dallas, Tex.
Jones, Jesse C. Newport News, Va.
Jones, Loyd W. Tulsa, Okla.
Jones, Oliver W. Van, Tex.
Jones, S. Clifford Cincinnati, Ohio
Jones, Walter F. Clarkson, Ky.
Jones, William E. Los Angeles, Calif.
Jopp, J. M. La Tuque, Quebec, Canada
Jorczak, Joseph S. Trenton, N. J.
Jorda, Robert M. Bakersfield, Calif.
Jordan, George W., III Atlanta, Ga.
Jordan, Harry E. New York, N. Y.
Jordan, Philip R. Mishawaka, Ind.
Jordan, Raymond C. Shreveport, La.
Jorgensen, Roy C. Freeport, Tex.
Joscak, Ralston F. New York, N. Y.
Jostes, Helmuth A. Abilene, Tex.
Joy, Austin S. Wilmington, Calif.
Joyce, Edwin Dallas, Tex.

Judah, Melvin A. ..... San Francisco, Calif.
Judge, James B. .. Newton, Mass.
Judge, Thomas J. .. Mobile, Ala.
Jungblut, Charles ..... Pont-a-Mousson, France
Juppenlatz, John W. Lebanon, Pa.
Jurs, Peter C. .. Berkeley, Calif.
Jursch, Charles F. ..... San Francisco, Calif.
Juster, Maurice W. ..... East Chicago, Ind.

K

Kahler, H. Lewis ..... Philadelphia, Pa.
Kahler, Leroy P. Jersey City, N. J.
†Kahn, Frank .. Philadelphia, Pa.
Kahn, Walter C., Jr. ..... Hazelton, Pa.
Kaim, Fred J. .. Minneapolis, Minn.
Kaletsch, K. G. ..... San Francisco, Calif.
Kalhauge, Viggo M. .. Chicago, Ill.
Kalin, Sumner H. ..... Vandergrift, Pa.
Kamps, Julius M. .. Pittsburgh, Pa.
Kaplan, Monte .. Dallas, Tex.
Karlskind, Don B. .. Houston, Tex.
Karraker, Ed. L. ..... East Chicago, Ind.
†Kartinen, E. O. ..... Los Angeles, Calif.
Kasper, Gordon E. ..... Van Nuys, Calif.
Kaster, J. W. ..... Tulsa, Okla.
Kattus, J. Robert ..... Birmingham, Ala.
Kauffman, David S. ..... Independence, Kan.
Kaufman, L. W. .. Mansfield, Ohio
Kaufmann, D. W. Buffalo, N. Y.
Kavenaugh, James A. ..... Los Angeles, Calif.
Kean, E. E. Jr. .. Amory, Miss.
†Keane, C. C. .. Kansas City, Mo.
Keaney, J. C. .. Pittsburgh, Pa.
Keating, Donald A. ..... Los Angeles, Calif.
Keaton, Lawrence C. Borger, Tex.
†Kedzie, Donald P. ..... Milwaukee, Wis.
Keeling, Harry J. ..... Los Angeles, Calif.
Keener, Joseph G. Pittsburgh, Pa.
Keith, James D. ..... Chattanooga, Tenn.
Keith, Roger S. .. Dallas, Tex.
Kellam, G. D. ..... Calgary, Alberta, Canada
Keller, Ralph W. ..... Colorado City, Tex.
Keller, Richard M. ..... Philadelphia, Pa.
Keller, W. H. .. St. Louis, Mo.
Keller, Wayne H. .. Waban, Mass.
Kellermann, August C. ..... Marcus Hook, Pa.
Kelley, Howard M. ..... Hyde Park, Mass.
Kelley, John H. Baltimore, Md.
Kelley, John V. Houston, Tex.
Kelley, Richard A. ..... Prairie Village, Kan.
Kellogg, Andrew Syracuse, N. Y.
Kelly, Bernard J. ..... Pittsburgh, Pa.
Kelly, J. Dyche .. Houston, Tex.
Kelly, Keith V. .. Mulberry, Fla.
Kelly, R. W. ..... Tulsa, Okla.
†Kelly, Thomas F. P. ..... Houston, Tex.
Kelly, Warner M. Houston, Tex.
Kelly, William M. ..... Toronto, Ontario, Canada
Kemper, E. O. ..... Odessa, Tex.
Kenan, Robert C. .. Chicago, Ill.
†Kendall V. V. .. Pittsburgh, Pa.
Kendrick, J. L. .. Kenner, La.
Kenelpp, Richard L., Jr. ..... Mt. Carmel, Ill.
Kennedy, Carl M. Springfield, Ill.
Kennedy, Frank M., Jr. ..... New York, N. Y.
Kennedy, Harvey T. ..... College Station, Tex.
Kennedy, James E. ..... Toronto, Ontario, Canada
Kennedy, Robert Malcolm ..... San Francisco, Calif.
Kennedy, Ted .. Ann Arbor, Mich.
Kennedy, W. L., Jr. .. Tulsa, Okla.
Kennison, Hugh F. ..... East Orange, N. J.
†Kentler, C. J., Jr. ..... Pittsburgh, Pa.
Kenyon, C. Patrick ..... Kansas City, Mo.
Kenyon, John S. .. Denver, Colo.
Kepley, Charles L. ..... Melvindale, Mich.
Keranen, John E. .. Chicago, Ill.
Kerby, Charles L. .. Broussard, La.
Kern, George P., Jr. ..... Wilmington, Del.
Kerns, Everette E. ..... Cleveland, Ohio
Kerr, James G. .. Alhambra, Calif.
†Kerr, R. H. .. Los Angeles, Calif.
Kerschner, Edward ..... Philadelphia, Pa.
Kerstein, Norman A. ..... Detroit, Mich.
Kessler, Kenneth K. ..... Baltimore, Md.
Ketcham, Brower .. Seattle, Wash.
Keyt, Ernest B. .. El Segundo, Calif.
Kiefer, George C. ..... Brackenridge, Pa.
Kilberg, Bernard .. Moline, Ill.
Kilburn, Thomas A. ..... New Kensington, Pa.
Kilday, John A. .. Dayton, Ohio
Killam, F. Richard ..... Vancouver, B. C.
Kimbley, J. Robert ..... Los Angeles, Calif.
Kimen, Peter A. .. Pasadena, Tex.
Kimmel, Albert L. ..... N. Kansas City, Mo.
Kinelski, Eugene H. ..... Pittsburgh, Pa.
†King, Leo, Jr. .. Mobile, Ala.
King, Leon F. New Orleans, La.
King, Raymond W. .. Bedford, Ohio
King, Robert J. .. Barber, N. J.
Kingsolver, James K. ..... New York, N. Y.
Kinley, John C. .. Houston, Tex.
Kinnear, Robert C. ..... Port Neches, Tex.
Kinney, Wayne L. .. Chicago, Ill.
Kirkendall, William E. ..... Los Angeles, Calif.
Kirkpatrick, Willard H. ..... Sugarland, Tex.
Kirsten, K. W. .. Dallas, Tex.
Kirwan, William F. ..... Baltimore, Md.
Kirwin, James E. ..... Aruba, Netherlands Antilles
Kizer, Curtis A. .. New Iberia, La.
Kizer, Flavil H. .. Lake Charles, La.
Klassen, Clarence W. ..... Springfield, Ill.
†Klauber, L. M. .. San Diego, Calif.
Kleber, John P. .. Pittsburgh, Pa.
Kleefisch, William .. St. Louis, Mo.
Kleespies, Henry S., Jr. ..... Port Arthur, Tex.
Klein, Fred M. .. New York, N. Y.
Klein, James C. .. Owensboro, Ky.
†Kleinheksel, S. Plainfield, N. J.
Klever, Charles F. .. Omaha, Neb.
Klinger, John C. Bayonne, N. J.
Klinger, Lloyd L. ..... Wisconsin Rapids, Wis.
Klinger, Oliver C. .. Houston, Tex.
Klopp, Edward M. ..... Cleveland, Ohio
Kluender, Arnold F. Chicago, Ill.
Klumb, George H. ..... Northbrook, Ill.
Klumb, Harvey J. ..... Rochester, N. Y.
†Knapp, Alfred P. ..... Long Island City, N. Y.
Knapp, Frederick F. ..... Fort Morgan, Colo.
Kneedler, Hugh A. ..... Brentwood, Mo.
Knickerbocker, Robert E. ..... Salem, Ill.
†Knight, C. A. .. Beaumont, Tex.
Knight, F. M. .. Los Angeles, Calif.
Knight, Henry Clay ..... Metuchen, N. J.
Knight, Hubert E. Amarillo, Tex.
Knopp, Harold P. Oakland, Calif.
Knowlton, A. E. New York, N. Y.
Knowlton, Drexel R. Avenal, Calif.
Knox, Frank A. .. Oak Ridge, Tenn.
Knox, John A. .. Midland, Tex.
Koch, C. E. ..... Chicago, Ill.
Koeckritz, E. Paul, Jr. ..... Los Angeles, Calif.
Koehler, W. A. ..... Morgantown, W. Va.
Koenig, E. A. .. Shreveport, La.
Koenig, William C. ..... Milwaukee, Wis.
Koester, H. F. New York, N. Y.
Koger, William C ..... Great Bend, Kan.
Koll, Robert J. .. Pasadena, Tex.
Kolzow, Clarence R. Elmhurst, Ill.
Kopetz, Geo. E. .. Pittsburgh, Pa.
Kopp, C. H. Oklahoma City, Okla.
Koppl, Frederick Milwaukee, Wis.
Kopplin, Julius O. ..... Hammond, Ind.
Kornmann, George L. ..... Washington, D. C.
Kosik, John A. Chattanooga, Tenn.
Kosteck, B. A. .. St. Louis, Mo.
Kozak, Stephen Toronto, Canada
*Kozakis, Achilles .. Houston, Tex.
Krebser, Adolf .. Basle, Switzerland
Krell, Abraham J. .. Houston, Tex.
Kretschmer, William J. ..... Columbus, Ohio
Krieg, Kenneth L. .. Wichita, Kan.
Krikscus, Paul, Jr. ..... Los Angeles, Calif.
Krisher, Albert S. Texas City, Tex.
Krockmalski, Edward ..... Corning, N. Y.
Kroon, Harry E. .. Chicago, Ill.
Krueger, Forrest J. ..... New York, N. Y.
Krueger, Jess J. .. Omaha, Neb.
Krueger, Louis T. .. Casper, Wyo.
†Kruger, R. E. .. Rochester, N. Y.
Kruse, Harry J. .. St. Louis, Mo.
Kruszynski, Edward A. ..... St. Louis, Mo.
Krystow, Paul .. Jersey City, N. J.
Kubicky, Edward W. ..... Newark, N. J.
Kuehnle, C. Albert, Jr. ..... Baltimore, Md.
Kuhlman, John L. ..... Beaumont, Tex.
Kuhlmann, Frank H. ..... Shreveport, La.
Kulman, Frank E. ..... New York, N. Y.
Kuhn, Robert J. ..... New Orleans, La.
Kunath, Richard P. ..... Las Piedras, E. F., Vene., S. A.
Kunetka, Robert E. .. Bellaire, Tex.
Kuniansky, I. .. Atlanta, Ga.
Kupfer, Robert R. ..... Milwaukee, Wis.
Kurtis, Soma .. Detroit, Mich.
Kurz, Fred E. .. Wilmington, Calif.
Kuzmich, Paul Nicholas ..... Pittsburgh, Pa.

L

Labuda, Joseph, Jr. ..... Calgary, Alberta, Canada
Lachmund, D. O. .. Newark, N. J.
Lacy, Cecil C. .. Spokane, Wash.
Lacy, J. Glen .. South Gate, Calif.
Ladd, Glenn L. ..... Independence, Kan.
Ladd, Raymond J. .. Midland, Mich.
Ladner, Frank Ellis ..... Vancouver, B. C., Canada
†La Fortune, J. A. .. Tulsa, Okla.
LaFortune, Robert J. ..... Tulsa, Okla.
Lafrenz, Albert .. Argo, Ill.
Lain, George D. .. New York, N. Y.
Laird, Wallace M. ..... Belleville, N. J.
Lake, Francis J. .. Queens, N. Y.
*Lamb, James C., III ..... Cambridge, Mass.
Lambert, Frank J., Jr. ..... Oak Ridge, Tenn.
Lambert, William R. Somerset, Pa.
Lamplugh, Jesse R. ..... Philadelphia, Pa.
Lancon, Albert A. Houston, Tex.
Landers, Charles R. ..... Fort Worth, Tex.
*Landers, James E. .. Dallas, Tex.
Landreneaux, John M., Jr. ..... Basile, La.
Lane, Bruce S. .. Kalamazoo, Mich.
†Lane, H. S. .. Houston, Tex.
Lane, Montie J. .. Philadelphia, Pa.
Lane, Russell W. .. Champaign, Ill.
Lang, Albert A. ..... East Cleveland, Ohio
Lang, E. Russell ..... South Gate, Calif.
Lang, Frances S. .. New York, N. Y.
Lang, Franklin New York, N. Y.
Langhans, Oscar .. Harvey, La.
Langhorst, Frederick H. ..... Natick, Mass.
Lanphier, Basil T. Reading, Pa.
Lantz, Willard J. .. Fords, N. J.
Laque, F. L. .. New York, N. Y.
†Larrabee, C. P. .. Vandergrift, Pa.
Larson, John A. .. Evanston, Ill.
Larson, Thurston E. .. Urbana, Ill.
Laster, Gaines .. Tulsa, Okla.
Lastrapes, Richard L. ..... Beaumont, Tex.
Lataille, Lester W. .. Honolulu, T. H.
Latham, Wallace L. ..... Oklahoma City, Okla.
Lattin, Benton C. ..... Scarsdale, N. Y.
Lauder, Andrew Allan ..... Winnipeg, Man., Canada
Lautner, Robert B. ..... Baton Rouge, La.
Lavery, C. A. .. Tulsa, Okla.
†Law, R. J. ..... Toronto, Ontario, Canada
Lawall, Russell M. .. Oberlin, Ohio
†Lawless, Sydney New York, N. Y.
Lawlor, E. W. .. Tulsa, Okla.
Lawn, Raymond J. ..... Pittsburgh, Pa.
Lawrence J. C. .. Twinsburg, Ohio
†Lawson, J. M. .. Lemont, Ill.
Lawson, Martin J. .. Boston, Mass.
Lawton, Ledra M. .. Lockport, N. Y.
Lay, Albert F. .. Houston, Tex.
Layman, Edward .. Pasadena, Tex.
Layne, Harold B. ..... Colorado City, Tex.
Leary, John D. ..... Corpus Christi, Tex.
Leas, A. Robert .. Washington, D. C.
Leblanc, Roland L. .. Aruba, N.W.I.
Lebrecht, G. Frank .. St. Louis, Mo.
Lecouff, Jesse .. Philadelphia, Pa.

Lecourt, Stanley M. ..... New Orleans, La.
Ledbetter, Buford P. ..... Corpus Christi, Tex.
Lederer, Lewis M. ..... Cincinnati, Ohio
Ledford, Robert C. .. Houston, Tex.
Lee, Bert E. .. Bellflower, Calif.
Lee, Charles E. ..... Los Angeles, Calif.
Lee, E. G. .. Houston, Tex.
Lee, Henry Amos ..... College Station, Tex.
Lee, James F. .. Beaumont, Tex.
Lee, R. P. .. South Amboy, N. J.
Lee, Robert H. .. Indianapolis, Ind.
Leedom, Laurie M. ..... Bloomfield, N. J.
Lefebure, Julius .. Santa Ana, Calif.
Lefebvre, Fabian J. .. Newark, N. J.
Lehmann, Joseph A. ..... New York, N. Y.
Leins, Ernest K. .. Syracuse, N. Y.
Leister, John A. .. Pittsburgh, Pa.
Leleux, C. J. .. Pittsburgh, Pa.
Lemay, Jack E. .. Dallas, Tex.
Lembcke, Richard E. Tallant, Okla.
Lemcke, Ewald M. Houston, Tex.
Lendved, John W. Milwaukee, Wis.
Leonard, Robert E. ..... Wilmington, Del.
Leonardon, Eugene Gilbert ..... Houston, Tex.
Leonhard, Frederick J. ..... Cleveland, Ohio
Lepley, Raymond D. ..... Philadelphia, Pa.
Leroy, Royce H. ..... College Station, Tex.
Lessuck, Bertram ..... Long Island City, N. Y.
Lester, C. B. .. Longview, Tex.
Levelton, Bruce H. ..... Vancouver, B. C., Canada
Levert, Wm. F. .. Shreveport, La.
Levinson, Irving S. ..... Milwaukee, Wis.
†Levy, David Henry .. Dallas, Tex.
Levy, Max M., Jr. Houston, Tex.
Lewis, David, II Kansas City, Mo.
Lewis, L. G. .. Midland, Tex.
Lewis, Sidney A. New York, N. Y.
Lewis, Walter T. .. Houston, Tex.
Libby, Hugh T. ..... Vancouver, B. C., Canada
Liebhafsky, Herman A. ..... Schenectady, N. Y.
Liebman, Arno J. ..... Pittsburgh, Pa.
Liggett, Ernest J. .. Tulsa, Okla.
Ligon, John R. Fort Worth, Tex.
Lima, D. O. Oklahoma City, Okla.
Limata, Albert J. New York, N. Y.
Lindberg, Jay G. .. Provo, Utah
Lindberg, Ramon I. .. Harvey, Ill.
Lindemann, Ervin ..... Minneapolis, Minn.
Linden, Bernard J. Bayonne, N. J.
Lindsay, J. D. College Station, Tex.
Lindsay, J. E. .. Johnstown, Pa.
Lindveit, G. M. .. Freeport, Tex.
Lineback, George A. ..... Cincinnati, Ohio
Linford, Henry B. ..... New York, N. Y.
Lipscomb, Thomas G., II ..... Baytown, Tex.
Lithgow, James ..... Los Angeles, Calif.
Little, Harry J. ..... Kennett Square, Pa.
Littreal, Wm. Bernard ..... Salt Lake City, Utah
Livengood, Robert G. ..... Shreveport, La.
Lobley, F. A. .. Elkhart, Ind.
Lobo, Humberto, Jr. ..... Monterrey, N. L., Mexico
Lochman, Walter J. ..... Berkeley, Calif.
†Locke, Giles .. Youngstown, Ohio
Locke, Norman W. ..... New York, N. Y.
†Lockeman, George F. ..... Cincinnati, Ohio
Lockhart, Frank J. ..... Los Angeles, Calif.
Lockwood, C. J. Beaumont, Tex.
Lockwood, Robert H. ..... Toronto, Ontario, Canada
Loeffler, John Edward ..... Houston, Tex.
Loeffler, William J. ..... Providence, R. I.
Loesch, Earl J. .. Tucson, Ariz.
Logan, Campbell F. ..... Jacksonville, Fla.
Logan, Hugh L. .. Washington, D. C.
Logan, Kirk H. Washington, D. C.
Logan, Robert L. .. Chicago, Ill.
Logie, John S. ..... North Vancouver, B. C., Canada
†Lomax, O. Q. .. Houston, Tex.
Lombardo, Flora South Gate, Calif.
Loncaric, Rado .. Dallas, Tex.
Long, Alfred .. Joliet, Ill.
†Long, Dan P. .. Amarillo, Tex.
Long, David E. New York, N. Y.

†Long, Frank V., Sr. Compton, Calif.
Longley, James E. East Orange, N. J.
Loomis, Francis E. New York, N. Y.
Loos, De Lasso Durango, Colo.
Lopato, Stanley L. St. Louis, Mo.
Loper, D. Roger San Francisco, Calif.
Lopez, Eugene R. New York, N. Y.
Loprete, Jack H. Detroit, Mich.
Lorber, Robert P. Springfield, Mass.
Lothringer, Robert L. Harvey, Ill.
Lotz, Paul L. Metuchen, N. J.
Loucks, Charles M. Cleveland, Ohio
Louviere, Bernard New Orleans, La.
Love, Billy Ray Carrizo Springs, Tex.
Love, Frank H. Dallas, Tex.
Love, James L. Lafayette, La.
Lovell, Odus W., Jr. Jackson, Miss.
Lovoi, Frank J. Houston, Tex.
Lowe, Marvin E. Barranquilla, Colombia, S. A.
Lowe, Richard A. Maracaibo, Venezuela
Lowenheim, Frederick A. Rahway, N. J.
†Lowerre, R. T. Cleveland, Ohio
†Lowther, G. B. St. Louis, Mo.
Loyd, Clyde C. Baker, La.
Luby, Michael A. Monroe, La.
Lucas, J. W. Ottawa, Ontario, Canada
Luce, Walter A. Dayton, Ohio
Lundberg, H. E. Stamford, Conn.
Luger, Karl E. Houston, Tex.
Luichinger, Martin J. Indianapolis, Ind.
Lundquist, Loyd M., Jr. Wilmington, Calif.
Lundy, Daniel A. Los Angeles, Calif.
†Lungren, E. E. Chicago, Ill.
Lusskin, Abraham Ridgefield, N. J.
Lutjens, Fred H. Sioux City, Iowa
Lutsch, William A. Detroit, Mich.
Luttrell, William T. Downingtown, Pa.
Lynch, Jack C. Long Beach, Calif.
Lynch, John P., Jr. Las Cruces, N. M.
†Lynch, Robert H. Philadelphia, Pa.
Lynes, Wilson Rome, N. Y.
Lyon, John A. M. Evanston, Ill.
Lyons, Robert H. Chicago, Ill.
Lyons, William C. Fort Worth, Tex.

Mc

McAmis, James W., Jr. Washington, D. C.
*McAninch, Don L. Pearland, Tex.
McAnneny, Adrian W. Houston, Tex.
McArdle, James P., Jr. Atlanta, Ga.
McAuliff, John P. Oklahoma City, Okla.
McBride, John S. New York N. Y.
McBrien, James H. Tulsa, Okla.
McCabe, Joseph C New York, N. Y.
McCall, Richard H. Houston, Tex.
McCallister, Robert V. New York, N. Y.
McCamish, Harley M. Avenal, Calif.
†McCammon, G. A. Caracas, Venezuela
McCammon, Thomas A. Cincinnati, Ohio
McCann, Sidney W. Rochester, N. Y.
McCarthy, Robert A. Dallas, Tex.
McCarvell, John H. Houston, Tex.
McCaslin, Kenneth M. South Gate, Calif.
McCauley, E. D. Birmingham, Ala.
McCauley, George M. Atlanta, Ga.
McClenahan, W. T. Chicago, Ill.
McClintock, Oliver Sewickley, Pa.
McClintock, Robert D. Waukesha, Wis.
McCloud, Dwite M. Santa Fe Springs, Calif.
McCluskey, Francis J. St. Louis, Mo.
McCollister, W. P. Bartlesville, Okla.
McComas, John Q. Los Angeles, Calif.
McComb Geo. B. St. Louis, Mo.
McConnell, Alexander Cudahy, Wis.
McConnell, Charles A. Middletown, Pa.
McConnell, Fred M. Los Angeles, Calif.
McConomy, Henry F. Philadelphia, Pa.
McCoppen, W. J. London, Ont., Canada
McCormick, Lawrence O. Baltimore, Md.
McCrackin, Francis A. Riverside, Calif.
McCrea, Walter H. Tipton, Iowa
*McCullough Harold M. Bayside, N. Y.
McCutchen, Charles W. Freeport, Tex.
McDaniel, John P. Harvey, La.
McDermott, Byron Oklahoma City, Okla.
†McDermott, Franklin New York, N. Y.
McDonald, Herschel C. San Antonio, Tex.
McDonald, Lawrence L. Chicago, Ill.
McDonald, Lewis A. Monsanto, Ill.
McDonald, T. B. Shreveport, La.
McDuffie, Roy O. Cincinnati, Ohio
McElhatton, Francis J. Kansas City, Mo.
McElroy, Charles R. Buffalo, N. Y.
McEwen, Cecil R. Paducah, Ky.
McFarland, Rolland, Jr. Chicago, Ill.
McGary, S. U. Houston, Tex.
*McGeary, Frank L. New Kensington, Pa.
McGee, Herbert S. Evanston, Ill.
†McGee, W. C. Houston, Tex.
*McGlothlin, Bruce B., Jr. Aberdeen Proving Grounds Maryland
McGrath, Martin H. Perth Amboy, N. J.
McGregor, James Odessa, Tex.
McHardy, George London, England
McIlhenny, G. N. Lake, Miss.
McIlrath, Samuel W. Painesville, Ohio
McIntosh, Russell W. Redondo Beach, Calif.
†McIntyre, G. H. Cleveland, Ohio
McKain, George D. Louisville, Ky.
McKee, Arvil B. New Kensington, Pa.
McKenney, Warren E. Houston, Tex.
McKenzie, T. Curtis Dearborn, Mich.
McKinney, T. Burns Midland, Tex.
McKirryher, Martin J. New York, N. Y.
McLaren, James Oakridge, Tenn.
McLaughlin, Harold A. Poughkeepsie, N. Y.
McLeese, Hugh D. Detroit, Mich.
McLelland, Archibald Dallas, Tex.
McMahon, George F. Chicago, Ill.
McManus, John J. Edgewater, N. J.
McMillan, W. A. Lake Charles, La.
McMullin, H. L. Dallas, Tex.
McNally, Robert J. Salt Lake City, Utah
McNamara, R. L. Haysville, Pa.
McNaughton, Walter F. Long Beach, Calif.
McNeill, John J. Melrose Park, Ill.
McNulty, Frank E. Tulsa, Okla.
McPherson, George M. Calgary, Alberta, Canada
McPherson, John L. Library, Pa.
McQueen, Wilbur C. Downington, Pa.
McRaven, C. H. Cocoli, Canal Zone
McSparran, W. G. Los Angeles, Calif.
†McWaters, R. J. Long Island City, N. Y.
McWhorter, Sam B. Woodbridge, N. J.
McWilliams, Robert J. Elyria, Ohio

M

Mabrey, William L. Tulsa, Okla.
Maccollum, Donald R. Rochester, N. Y.
Maccorkle, Daniel S. Hoboken, N. J.
Maccormack, Robert S., Jr. Mountain Lakes, N. J.
Macdermond, Elliott Philadelphia, Pa.
*Macdonald, A. John Pittsburgh, Pa.
Macdonald, Frank P. Chicago, Ill.
Mac Gregor, Alfred H. Webster Groves, Mo.
Mach, Walter W. Houston, Tex.
Machado, Oscar Caracas, Venezuela
Macias-Rendon, Fernando Monterrey, N. L., Mex.
Mack, Bernhard V. Richmond, Calif.
Mack, David J. Madison, Wis.
Mackenzie, James T. Birmingham, Ala.
Mackenize, John B., Jr. Houston, Tex.
Mackinnon, W. R. Culver City, Calif.
Macleod, John A. New York, N. Y.
Madden, R. C. Provo, Utah
Maddox, Melvin E. Tulsa, Okla.
Madero, Carlos F. Monterrey, Mex.
Madigan, James F. Philadelphia, Pa.
Maggiacomo, Sam Toronto, Canada
Magoffin, Linn E. National City, Calif.
†Maher, D. W. Detroit, Mich.
Mahlmann, Alfred New York, N. Y.
†Mahoney, E. J. Jr. Lansing, Mich.
Maier, R. William Pittsburgh, Pa.
Main, Merrill M. Chicago, Ill.
Maitland, T. J. New York, N. Y.
Major, Lewis A. Alexandria, Va.
Makepeace, Charles E. Welland, Ont., Canada
†Malcom V. V. Cincinnati, Ohio
Malley, Henry A., Jr. Kansas City, Mo.
Malley, Robert J. Kansas City, Mo.
*Malone, Maurice O. Baton Rouge, La.
Maloney, Richard W. Los Angeles, Calif.
Mandell, Bernard Azusa, Calif.
Mandley, John O. Detroit, Mich.
Mange, Clarence E. St. Louis, Mo.
Mangold, Alfred O. Portland, Oregon
†Mankin, Paul A. Fort Wayne, Ind.
Manley, Harold W. Tulsa, Okla.
†Mann, L. D. Lake Charles, La.
Manninen, Thomas H. Baltimore, Md.
†Manning, Paul D. V. Skokie, Ill.
Maradudin, Alexei P. El Segundo, Calif.
Markham, Wendell G. Long Beach, Calif.
Markle, Mathew G. Bellwood, Ill.
Markoff, Daniel Los Angeles, Calif.
Marlin, Donald H. Pittsburgh, Pa.
Marquez, Edward B. New Orleans, La.
Marquis, Samuel A. Washington, D. C.
†Marrinan, J. W. Pittsburgh, Pa.
Marsal, M. P. New Orleans, La.
Marsh, William F. Boston, Mass.
Marshall, Dwight New York, N. Y.
Marshall, Fred D. Los Angeles, Calif.
Marshall, Jerry R. Erath, La.
Marshall, Robert P. Detroit, Mich.
Martin, Arthur R. Milwaukee, Wis.

†Martin, H. M. Houston, Tex.
Martin, Bertell E. Los Angeles, Calif.
Martin, Harry C. Monroe, La.
Martin, Jack T. New Orleans, La.
Martin, James H., Jr. Baytown, Tex.
Martin, Paschal Chicago, Ill.
Martin, Robert C. Atlanta, Ga.
Martin, Roger E. Elizabeth, N. J.
Martin, W. Edgar San Francisco, Calif.
*Martinello, Carl P. Malden, Mass.
Marx, Paul F. Bradford, Pa.
Masin, Charles B. Denver, Colo.
Mason, John F., Jr. New York, N. Y.
Mason, John R. Tulsa, Okla.
Massimini, S. Vincent, Jr. New Orleans, La.
Massing, Robert W. Chicago, Ill.
Massuet, Vicente Barcelona, Spain
Mathers, W. D. Huntington, N. Y.
†Matson, Eugene M. Des Plaines, Ill.
Matthews, James C. Houston, Tex.
Mauney, L. M. Tulsa, Okla.
Maw, J. T. Cartagena, Colombia, S. A.
Maxwell, Eugene C. Denver, Colo.
May, Kendall B. Ann Arbor, Mich.
May, Thomas P. New York, N. Y.
Mayer, William J. Baltimore, Md.
†Mayer, William M. Corpus Christi, Tex.
Mayes, Edward San Francisco, Calif.
Mayes, H. B. Houston, Tex.
†Mayo, E. E. San Francisco, Calif.
Mead, Albert Raynor Bethpage, N. Y.
Mead, William J. Elkhart, Ind.
Meader, Raymond B. Boston, Mass.
Means, Ben H. Houston, Tex.
Meany, John J., Jr. Ardmore, Pa.
Mears, Robert B. Pittsburgh, Pa.
Meek, J. Gordon Dallas, Tex.
Meeker, Olin W. Long Beach, Calif.
Meier, Alfred O. New York, N. Y.
Meier, Ernest F. St. Louis, Mo.
Meigs, W. H. Oklahoma City, Okla.
Mendive, Anthony J. Houston, Tex.
Mendizza, August Murray Hill, N. J.
Mengel, Arthur C. Schenectady, N. Y.
Menhinick, Walter E. Huntington Park, Calif.
Mensch, Harold F. Franklin Park, Ill.
Mensch, Ralph G. Chicago, Ill.
Mercer, C. L. Houston, Tex.
Mercer, Kenneth K. Houston, Tex.
Mercer, Robert S. Philadelphia, Pa.
Merrick, R. D. Garwood, N. J.
Merrill, H. William, Jr. Dayton, Ohio
Merrill, Harry E. Buffalo, N. Y.
Merrill, Timothy W. New York, N. Y.
Merwin, Albert E. New York, N. Y.
Merwin, Walter J. Orland Park, Ill.
Meserve, Ralph H. St. Paul, Minn.
Messick, W. C. Santa Fe Springs, Calif.
Metzger, Paul D. Pittsburgh, Pa.
Meyer, B. W. Oklahoma City, Okla.
Meyer, Frederick R. New Haven, Conn.
†Meyer, Philip A. New York, N. Y.
Meyer, Rene P. Baltimore, Md.
Meyer, Robert H. Independence, Kan.
Meyer, Walter B. St. Louis, Mo.
Michael, Lewis E. Dayton, Ohio
Michaud, M. L. Los Angeles, Calif.
Mickelson, Alfred O. Stonington, Mich.

Middaugh, H. B. ..... Fort Wayne, Ind.
Mikesell, William H. ..... Chicago, Ill.
Miles, John A. ..... New York, N. Y.
†Millar, Maury ..... San Francisco, Calif.
Miller, Carl F., Jr. ..... Philadelphia, Pa.
Miller, Charles E. Milwaukee, Wis.
Miller, Donald M. ..... Los Angeles, Calif.
Miller, Donald N. ..... Los Angeles, Calif.
Miller, Dwight L. ..... Wyandotte, Mich.
Miller, Edward C. ..... Oak Ridge, Tenn.
Miller, Eldon F. ..... New York, N. Y.
Miller, Harry J. ..... Dallas, Tex.
Miller, Harvey S. ..... Brookline, Mass.
Miller, Howard C. ..... Grand Saline, Tex.
†Miller, Jack C. ..... Houston, Tex.
Miller, James D. ..... Azusa, Calif.
Miller, John J. ..... Pittsburgh, Pa.
†Miller, M. C. ..... Allendale, N. J.
Miller, Murray R. ..... Hoboken, N. J.
†Miller, Pat H. ..... Shreveport, La.
Miller, Paul Thomas ..... Houston, Tex.
†Miller, Ralph D. ..... Pittsburg, Kansas
Miller, Ross F. ..... Emeryville, Calif.
Milling, Dan J. ..... Houston, Tex.
Mills, E. J. ..... Snyder, Tex.
Mills, James L. ..... Oil City, Pa.
Mills, Lester D., Jr. ..... Cleveland, Ohio
Mills, Orville L. ..... Edgewater, N. J.
Mills, Richard P. ..... Freedom, Pa.
Mills, Walter W. ..... Bakersfield, Calif.
†Millsop, T. E. ..... Weirton, W. Va.
Miltenberger, Gustave ..... New Orleans, La.
†Miltner, Donald E. ..... Wichita, Kan.
Miner, Lucien L., Jr. ..... Houston, Tex.
Minnick, Arvel L. ..... Shawnee, Okla.
Minor, Alton F. ..... Jackson, Miss.
Minter, James F. ..... Donaldsonville, La.
Mintz, Bernard ..... Culver City, Calif.
Misch, Robert D. ..... Lemont, Ill.
Mitchell, E. B. ..... Houston, Tex.
Mitchell, Francis H. ..... Los Angeles, Calif.
Mitchell, Frank G. ..... Vancouver, B. C., Canada
Mitchell, Frank K. ..... New York, N. Y.
Mitchell, Malcolm ..... Indianapolis, Ind.
Mitchell, Marvin G. ..... Atlanta, Ga.
†Mitchell, N. W. ..... Waterbury, Conn.
Mitchell, Richard E. ..... New York, N. Y.
Mixer, Richard A. ..... Philadelphia, Pa.
Mize, Woodrow W. ..... Farmington, N. M.
Mobley, Garner C. ..... Savannah, Ga.
Mock, Guy C. ..... Houston, Tex.
Moehrl, Kenneth E. ..... Memphis, Tenn.
Moffatt, Thomas S., Jr. ..... Corpus Christi, Tex.
Moffett, J. L. ..... Lima, Ohio
Mohler, Richard W. ..... Pittsburgh, Pa.
Mohr, Bernard ..... London, England
Molcar, Charles P. ..... Chicago, Ill.
Moller, George E. ..... Rodeo, Calif.
Moller, John H. ..... San Leandro, Calif.
Molnar, Eric G. ..... Caracas, Venezuela
Momoi, James ..... South Milwaukee, Wis.
Moncrief, R. S. ..... Shreveport, La.
Monson, Louis T. ..... Los Angeles, Calif.
Montague, Donald E. ..... Houston, Tex.
Montel, Joseph I. ..... New York, N. Y.
Montemurro, Michael M. ..... Toronto, Ont., Canada
Montgomery, Allen M. ..... Cleveland, Ohio
Montgomery, Ben C. ..... Toledo, Ohio
Montgomery, Clyde W. ..... St. Louis, Mo.
Montgomery, Paul ..... Lafayette, La.
Montgomery, Wayne C. ..... New Orleans, La.
Moore, Albert E. ..... Camden, N. J.
Moore, Clyde N. ..... Long Beach, Calif.
Moore, Laban T. ..... Catlettsburg, Ky.
Moore, Orville E. ..... Zionsville, Ind.
*Moore, Paul S. ..... Odessa, Tex.
Moore, Roy W. ..... Brooklyn, N. Y.
Moore, W. B. ..... Louisville, Ky.
†Moorman, Earl F. ..... Chicago, Ill.
Moran, W. T. ..... Houston, Tex.
Morcom, Robert S. ..... New Iberia, La.
Morell, Forrest L. ..... Phoenix, Ariz.
Morgan, C. L. ..... Houston, Tex.
Morgan, Homer C. ..... Houston, Tex.
Morgan, T. A. ..... Houston, Tex.
Morgan, Zane V. ..... Seguin, Tex.
Mori, John Y. ..... Chicago, Ill.
Morris, Clarence S. ..... Los Angeles, Calif.
Morris, H. E. ..... Texas City, Tex.
Morris, James F. ..... Chicago, Ill.
Morris, James I. ..... Billings, Mont.
Morrison, Barclay ..... Union, N. J.
Morrison, D. B. ..... Gary, Ind.
Morrison, Jacob B. ..... Midland, Pa.
Morrison, John G. ..... Philadelphia, Pa.
Morrow, Hal Pat ..... Dallas, Tex
Morrow, Orville E. ..... San Francisco, Calif.
Morrow, William G. ..... Newark, N. J.
Morse, Arley Edwin ..... Coloma, Mich.
Morse, Murray E., Jr. ..... New York, N. Y.
†Morse Robert E. ..... New York, N. Y.
Mortel Joseph P. ..... New Britain, Conn.
Morton, Byron B. ..... New York, N. Y.
Morton, David F. ..... Birmingham, Ala.
Moseley, E. L. ..... Houston, Tex.
Mosher, Malcolm ..... Quincy, Mass.
Mosier, Benjamin ..... Fort Worth, Tex.
Moss, Charles F., Jr. ..... Wilmington, Del.
Mount, W. R. ..... Edmonton, Alberta, Canada
*Movius, John D. ..... Hoboken, N. J.
Moyar, Robert E. ..... Rouseville, Pa.
Moyer, Fred ..... Chicago, Ill.
Moyle, M. W. ..... Rosita, Coah., Mex.
Mrazek, Frank W. ..... New Orleans, La.
Mudd, O. C. ..... Houston, Tex.
Muehlhause, Edwin H. ..... Dallas, Tex.
Mueller, Max F. Phillipsburg, N. J.
Mueller, R. E. ..... Minneapolis, Minn.
Muery, Sam J., Jr. ..... Freeport, Tex.
Muirhead, D. A. ..... Shreveport, La.
Mulcair, Jeremiah J. ..... New York, N. Y.
Mulheran, Bernard C. ..... Bay Village, Ohio
Mullendore, John A. ..... St. Louis, Mo.
Muller, Herman, Jr. ..... New York, N. Y.
Muller, L. Phillip Philadelphia, Pa.
Mullin, Grover E. ..... Ardmore, Pa.
Mullins, John D. ..... Houston, Tex.
Mullins, Sidney O. ..... Gary, Ind.
Mumford, Thomas R. ..... Pittsburgh, Pa.
Mundt, H. W. ..... Rodman, Canal Zone
†Munger, C. G. ..... South Gate, Calif.
Munro, John D. ..... Scotch Plains, N. J.
Murphy, Arthur N. ..... London, England
Murphy, Ashley T. ..... Los Angeles, Calif.
Murphy, G. J. W. ..... Bellaire, Tex.
Murphy, John P. ..... Chicago, Ill.
Murray, Christopher A. ..... Nederland, Tex.
Murray, William B. ..... Long Beach, Calif.
Murrey, O. E. ..... Tulsa, Okla.
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†Muss, David ..... New York, N. Y.
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†Myers, W. R. ..... Wilmington, Del.

N

Nadas, Michael C. ..... Toronto, Ont., Canada
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Napack, Marvin ..... River Edge, N. J.
Naremore, James D. ..... West Monroe, La.
Nasmith, D. F. ..... Arvida, Quebec, Canada
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†Neher, Frank H. ..... New York, N. Y.
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Oxley, George W. ..... Elizabeth, N. J.

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Plym, Lester M. Chicago, Ill.
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Robbins, Kenneth W. Dallas, Tex.
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Robinson, Harold A. Midland, Mich.
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Russell, John C. Albuquerque, N. M.
Rutemiller, Herbert C. Cleveland, Ohio
Rutherford, John J. B. Beaver Falls, Pa.
Rutter, Charles M., Jr. Pittsburgh, Pa.
Rydell, Robert G. Chicago, Ill.
†Ryznar, J. W. Chicago, Ill.

S

Sadoulet, Maurice Lyon Rhone, France
Sage, John F. Tulsa, Okla.
Sales, Mario Torino, Italy
Salinger, Richard Fisk Orlando, Fla.
Salle, William H. Chicago, Ill.
Salmon, Philip A. Newark, N. J.
Sample, Clarence H. New York, N. Y.
Sampson, Stephen S. Houston, Tex.
Sandberg, Paul A. Cicero, Ill.
Sandborg, Ogden W. Chicago, Ill.
Sandel, Walter J. Glenmont, Ohio
Sanders, W. S., Jr. Washington, D. C.
Sanderson, Austin O. El Segundo, Calif.
Sanderson, Wiley D. Detroit, Mich.
Sandor, John G. Cleveland, Ohio
†Sands, George A. New York, N. Y.
Sandford, Robert D. St. Louis, Mo.
Saulson, Saul Detroit, Mich.
†Saunders, H. O. New York, N. Y.
Saunders, William F. Los Angeles, Calif.
Savage, Robert H. Los Angeles, Calif.
Saye, Hugh A., Jr. Houston, Tex.
Scamman, Chas. W. Houston, Tex.
Scarola, V. J. Evanston, Ill.
Scarpa, Oscar Como, Italy
Schaefer, Leonard P. Detroit, Mich.
Schaefer, Ralph A. Cleveland, Ohio
Schaller, Charles C. New Orleans, La.
Schaschl, Edward Park Ridge, Ill.
Schauers, Joseph A. Philadelphia, Pa.
Scheil, Merrill A. Milwaukee, Wis.
†Scherer, Lewis F. Houston, Tex.
Schereschewsky, P. L. Paris, France
Schermer, Richard Dayton, Ohio
Schick, William F., Jr. Tulsa, Okla.
Schiff, Melvin J. Monrovia, Calif.
Schiller, Alfred F. East St. Louis, Ill.
Schilling, W. M. Bell, Calif.
Schindler, Albert L. Boston, Mass.
Schlather, Max F. San Antonio, Tex.
Schlaudt, Clarence A. Trona, Calif.
Schleicher, Martin E. Buffalo, N. Y.
Schley, John R. Kokomo, Ind.
Schlossberg, Louis Conshohocken, Pa.
Schlueter, August New York, N. Y.
Schmeeckle, Duane A. Calgary, Alberta, Canada
Schmid, Charles F. Seymour, Conn.
Schmidt, Burton J. Deerfield, Ill.
Schmidt, Fred A. Houston, Tex.
Schmidt, Herbert W. Midland, Mich.
†Schmidt, Karl E. Detroit, Mich.
Schmidt, Robert J. Richmond, Calif.
Schmidt, R. W. Sierra Madre, Calif.
Schmidt, R. W. Lake Jackson, Tex.
Schmieding, Earl G. St. Louis, Mo.
†Schmierer, A. F. Beatrice, Neb.
Schmitz, Carl Edward Chicago, Ill.
Schmitz, Fred W. Terre Haute, Ind.
Schmuck, G. Gordon Chicago, Ill.
Schmuck, Howard K., Jr. Denver, Colo.
Schneider, Charles L. Newark, Ohio
Schneider, Frederick W. Woodhaven, N. Y.
Schneider, John H. Whitefish Bay, Wis.
†Schneider, Wm. R. Emeryville, Calif.
Schofer, Nathan Wichita, Kan.
Schofield, Cecil Cleveland, O.
†Schofield, L. J. Kansas City, Mo.
Scholbe, J. L. Philadelphia, Pa.
Scholl, Russell C. Houston, Tex.
Schoonover, Wayne D. Houston, Tex.
Schor, Milton Chester, Pa.
Schram, Irwin H., Jr. Pittsburgh, Pa.
Schreiner, William J. Cincinnati, Ohio
Schreitz, Wm. Gordon Annapolis, Md.
Schroeder, Charles D. Amarillo, Tex.
Schroeder, Clarence E. Milwaukee, Wis.
Schroth, Charles R. Haddon Heights, N. J.
Schroth, Harry A. Glendive, Mont.
Schueler, Robert C. Bartlesville, Okla.
Schueneman, Harry H., Jr. Chicago, Ill.
†Schuh, A. E. Burlington, N. J.
Schuhmacher, Gordon S. South Gate, Calif.
†Schultz, R. F. Wilmington, Del.
Schulze, Robert E. Northbrook, Ill.
Schumacher, Henry R. Wilmington, Calif.
Schupp, Carleton H. Westwego, La.
Schustack, Edward H. Huntington Park, Calif.
Schutt, Russell W. New Orleans, La.
Schwab, Carl M. Dallas, Tex.
Schwalm, Lawrence H. Cleveland, Ohio
Schwob, Robert D. Chicago, Ill.
Scollay, Kenneth L. Detroit, Mich.
Scott, F. L. Carteret, N. J.
Scott, Gordon N. Los Angeles, Calif.
Scott, Harold H. Martinez, Calif.
Scott, John Bradford Pasadena, Tex.
Scott, Paul T. Ft. Worth, Tex.
Scott, T. C. Kokomo, Ind.
†Scott, W. R. La Habra, Calif.
Scowcroft, Gordon C. Montreal, Queb., Canada
Scribner, Leonard Lake Bluff, Ill.
Scull, William L. Colorado Springs, Colo.
Seagren, G. W. Pittsburgh, Pa.
Seal, Wm. D. Indianapolis, Ind.
Seaman, F. Eugene Wharton, N. J.
Seaman, Edward S. Baldwin, N. Y.
Searcy, John E., Jr. Lewisville, Ark.
Searer, Jay C. North Tonawanda, N. Y.
†Sears, D. F. Houston, Tex.
Sears, Edward C. Birmingham, Ala.
Seay, Ernest W., Jr. Norfolk, Va.
Sebestik, Aldrich E. Springfield, Ill.
Secrest, Leslie C. Ponca City, Okla.
†Sedgeman, W. H. Toledo, Ohio
Seafeld, Carl J. Houston, Tex.
Segel, Kalman Aruba, Netherland Antilles
Seidel, G. E. Chicago, Ill.
Seidenstricker, R. A. Milwaukee, Wis.
Seidman, Stanley M. Cleveland, Ohio
Seifert, Richard Lester Hamburg, N. Y.
Seifried, Dean B. Spring Valley, N. Y.
Seitz, George H., Jr. Wilmington, Del.
Selle, Joseph B. Houston, Tex.
†Senatoroff, N. K. Los Angeles, Calif.
Sennett, Walter M. Mountain View, N. J.
Seppa, K. E. Berkeley, Calif.
Serbula, Steve, Jr. Chicago, Ill.
Serenco, Harvey St. Louis, Mo.
Serven, Edward J., Jr. Clifton, N. J.
Sesher, William A. Emmaus, Pa.
Severance, Wesley A. Cleveland, Ohio
Sevin, Lloyd L. New Orleans, La.
Sexton, Earl M. Toledo, Ohio
Seyl, Robert G. Evanston, Ill.
Seymour, Raymond B. Mertztown, Pa.
†Shackelford, R. E. Tulsa, Okla.
Shaffer, George E., Jr. Philadelphia, Pa.
Shaffer, James A., Jr. San Francisco, Calif.
Shaffer, Percy C. Hillside, N. J.

Shaffner, Richard H. ..... Niagara Falls, N. Y.
Shankweiler, Fred K. ..... Wilmington, Del.
Shapiro, Myer ..... Boston, Mass.
Share, Martin ..... Chicago, Ill.
Sharpe, L. G. ..... Houston, Tex.
Sharpnack, E. V. ..... Louisville, Ky.
Shaw, A. G. ..... North Little Rock, Ark.
Shaw, Minot M. ..... Boston, Mass.
Shaw, William E. ..... Cincinnati, Ohio
Shay, Neil E. ..... Dallas, Tex.
Sheard, Walter G., Jr. ..... Seaford, N. Y.
Shearon, Kervin B. ..... Houston, Tex.
Sheets, Macon ..... Corpus Christi, Tex.
Sheffer, James W. ..... Philadelphia, Pa.
Sheldahl, David B. ..... Harvey, Ill.
Shelton, Johnny H. ..... Midland, Tex.
Shelton, M. J. ..... La Mesa, Calif.
Shelves, Arthur R. ..... Chicago, Ill.
Shemilt, Leslie W. ..... Vancouver, Canada
Shenton, F. George ..... Monroeville, N. J.
Shepard, Arthur P. ..... Flushing, N. Y.
Shepherd, Clayton C., Jr. ..... Los Angeles, Calif.
Shepard, Edgar Raymond ..... Arlington, Va.
Shepard, H. C. ..... New York, N. Y.
Shepard, Harry L. ..... Houston, Tex.
Shepard, Spencer W. ..... Linden, N. J.
Sheppard, Joseph E. ..... Cleveland, Ohio
Sheppard, Lyle R. ..... Houston, Tex.
Sheppard, Walter Lee, Jr. ..... Philadelphia, Pa.
Sherer, Clayton M. ..... Holtwood, Pa.
Sherman, Carl L. ..... Brockville, Ont., Canada
Sherman, Charles H. ..... San Mateo, Calif.
Sherwood, B. C. ..... Chicago, Ill.
Sherwood, William C. ..... South Boston, Mass.
Shidler, Norman T. ..... Pittsburgh, Pa.
Shields, James E. ..... Niagara Falls, N. Y.
Shields, Morton K. ..... Van Nuys, Calif.
Shier, Manneth ..... Jersey City, N. J.
Shigeno, Hayata ..... Tokyo, Japan
Shigley, C. M. ..... Freeport, Tex.
Shingle, John Hayne ..... Cisco, Tex.
Shinnamon, Charles W. ..... Silver Springs, Md.
Shipman, Waldo A. ..... Falls Church, Va.
Shipps, Arthur W. ..... Oakland, Calif.
Shnidman, Louis ..... Rochester, N. Y.
Shoan, Raymond A. ..... Chicago, Ill.
Shobe, E. H. ..... Corpus Christi, Tex.
Shobe, O. F. ..... Cleveland, Ohio
Shock, D. A. ..... Ponca City, Okla.
Shoemaker, Raymond T. ..... Dallas, Tex.
Shoenberger, Winston A. ..... Shreveport, La.
Sholtis, George E. ..... Akron, Ohio
Shonafelt, Austin E. ..... Bakersfield, Calif.
Shoop, John W. ..... Cleveland, Ohio
Shoor, Abraham ..... Haifa, Israel
Short, Glenn P. ..... St. Louis, Mo.
Short, Howard E. Cincinnati, Ohio
Shoumatoff, Nicholas ..... New York, N. Y.
Shugart, Brock ..... Houston, Tex.
Shuldener, Henry L. ..... New York, N. Y.
Shupp, Carl W. ..... Glendale, Calif.
Shutt, George T. ..... St. Louis, Mo.
Shutt, J. Daniel ..... Ardmore, Pa.
Sibille, Vernon Q. ..... Lafayette, La.
Sibley, Robert S. ..... St. Louis, Mo.
Sickman, Edison C. ..... New York, N. Y.
Siddall, D. F. ..... Akorn, Ohio
Siebert, C. A. ..... Ann Arbor, Mich.
Siebert, H. E. ..... Toronto, Ont., Canada
Siess, Charles P., Jr. ..... Monroe, La.
Silberstein, Milton L. ..... Houston, Tex.
Silkworth, George H. ..... New York, N. Y.
Sill, George H. Philadelphia, Pa.
Sills, T. O. ..... Kannapolis, N. C.
Simmons, Edward E., Jr. ..... Pasadena, Calif.
Simmons, Edward J. ..... Dallas, Tex.
Simmons, William P. ..... San Francisco, Calif.
Simmons, Joseph C. ..... New Haven, Conn.
Simon, Allan ..... Harrison, N. J.
Simons, Gordon F. ..... Reading, Pa.
Simpson, A. D., Jr. ..... Houston, Tex.
Simpson, John B. ..... Jackson, Mich.
Simpson, N. H. ..... Fort Worth, Tex.
Sims, C. I. ..... Dallas, Tex.
Sims, John J. ..... Canyon, Tex.
Sinclair, Edward L. ..... New York, N. Y.
Sinclair, W. Allistair ..... Detroit, Mich.
Singleton, Walter T., Jr. ..... El Paso, Tex.
Skeie, Kermit ..... Chicago, Ill.
Skinner, Edmond N., Jr. ..... New York, N. Y.
Skinner, Ralph B. ..... Edmonton, Alberta, Canada
Skinner, S. D. ..... Buffalo, N. Y.
†Skog, Ludwig, Jr. ..... Chicago, Ill.
Slavik, Edward W. ..... Corpus Christi, Tex.
*Sledge, B. L. ..... Houston, Tex.
†Sline, Louis ..... Houston, Tex.
†Slough, Ralph M. Findlay, Ohio
Slover, Charles L. ..... Dallas, Tex.
Slunder, Charles J. ..... Columbus, Ohio
Small, Charles S. New York, N. Y.
Smiley, Charles B. ..... Fairless Hills, Pa.
Smith, Adrian W. ..... San Francisco, Calif.
Smith, Alonzo L. Houston, Tex.
Smith, Arthur E. ..... Jacksonville, Fla.
Smith, Bertram M. ..... Los Angeles, Calif.
Smith, Carl B. ..... Chicago, Ill.
Smith, Carl M. ..... Houston, Tex.
Smith, Cecil O. ..... Tulsa, Okla.
Smith, Clair J. Bakersfield, Calif.
Smith, Clarence W. ..... Philadelphia, Pa.
Smith Claude B. ..... San Francisco, Calif.
Smith, C. W. ..... Crossett, Ark.
Smith, Don C. Port Arthur, Tex.
Smith, Douglas V. ..... Shreveport, La.
Smith, Eben O. ..... West Medford, Mass.
Smith, H. D. ..... Halifax, N. S., Canada
Smith, Harold L. Kansas City, Mo.
Smith, James New York, N. Y.
Smith, James L. ..... Westlake, La.
Smith, James M. ..... Raceland, La.
Smith, Joseph Roy ..... Shreveport, La.
Smith, Joseph W. ..... Chicago, Ill.
Smith, Lyle R. ..... Ogallala, Neb.
Smith, Martin B. Pasadena, Calif.
Smith, Martin H. Mertztown, Pa.
†Smith, O. R. ..... Fort Worth, Tex.
†Smith, Philip H. ..... St. Louis, Mo.
Smith, Randal E. ..... Carlsbad, N. M.
†Smith, Rex L. ..... Tulsa, Okla.
Smith, Robert J. ..... Chicago, Ill.
Smith, Robert M. ..... Houston, Tex.
Smith, Roy B. ..... Erwina, Pa.
Smith, Roy H. ..... Seattle, Wash.
Smith, Sydney S. ..... New York, N. Y.
Smith, Sidney V. ..... Houston, Tex.
Smith, Theodore J. ..... San Francisco, Calif.
Smith, Tracy E. ..... Dallas, Tex.
†Smith, Turner C. ..... Los Angeles, Calif.
Smith, Vaughn R. ..... Richmond, Calif.
Smith, Vernon R. ..... Massillon, Ohio
Smith, Walter R. ..... Buffalo, N. Y.
Smith, William A. ..... East Point, Ga.
Smith, Wm. B. Jr. ..... Shreveport, La.
Smith, William E., Jr. ..... Cleveland, Ohio
Snashall, Earl H. ..... Columbus, Ohio
Snedaker, Delbert G. ..... Houston, Tex.
Snell, Clark A. ..... New York, N. Y.
Snider, Henry I. ..... South Gate, Calif.
†Snook, Joseph A. Mertztown, Pa.
†Snyder, B. W. ..... Calgary, Alberta, Canada
Snyder, Fred B. ..... Alliance, Ohio
Snyder, Kenneth T. ..... Houston, Tex.
Snyder, Louis A. ..... Wilmington, Calif.
Soley, R. Clyne ..... Cambridge, Mass.
Soll, Rolland H. ..... San Bernardino, Calif.
†Somerville, R. B. ..... Ada, Mich.
Sonntag, Charles E., Jr. ..... Texas City, Tex.
Sosnin, H. A. ..... Jenkintown, Pa.
South, John R. ..... Cincinnati, Ohio
Spackman, Grant L. ..... Edmonton, Alberta, Canada
Spafford, Perry Parker ..... Houston, Tex.
Spalding, Donald A. ..... Midland, Mich.
Spalding, James C., Jr. ..... Dallas, Tex.
Spangenberg, Robert F. ..... West Allis, Wis.
*Sparks, Jack Lee ..... Norman, Okla.
Sparks, Robert E. ..... East McKeesport, Pa.
Sparrow, Lionel R. Homs, Syria
Spector, Dov ..... Tel-Aviv, Israel
Speller, Frank N. ..... Pittsburgh, Pa.
Spencer, Kenneth A. ..... London, England
†Spencer, S. F. Philadelphia, Pa.
Speyer, Walter G. ..... New York, N. Y.
Spilman, Ramon D. ..... Sulphur, La.
Spinks, Lee N. ..... New Orleans, La.
Spoehr, Thomas F. ..... Morton Grove, Ill.
Spooner, Leonard G. Jr. ..... Carteret, N. J.
Sprague, E. Richard ..... Compton, Calif.
Spraul, J. Robert ..... East Chicago, Ind.
Sprowls, Donald O. ..... New Kensington, Pa.
Stafford, Edwin O. ..... Houston, Tex.
Stafford, Jay D. ..... Midland, Tex.
Staley, Harold B. ..... Philadelphia, Pa.
Stalker, Marion H. ..... Los Angeles, Calif.
Stamper, Furman H. ..... North Hollywood, Calif.
Stanley, Alfred H. ..... Chicago, Ill.
Stanley, John W. ..... Charleston, Mass.
Stanton, W. L. ..... Sheverport, La.
Staples, William R. ..... Union, N. J.
Starbird, L. C. ..... Dallas, Tex.
Stark, Paul H. ..... Tulsa, Okla.
Stark, Richard I. ..... Concord, Calif.
Statham, Tom R. ..... Dallas, Tex.
Stauffacher, E. R. ..... Los Angeles, Calif.
†Stearns, D. E. ..... Shreveport, La.
Stearns, Ned C. ..... Shreveport, La.
Steckelberg, John F. ..... Lake Charles, La.
Steel, Edward W. Pittsburgh, Pa.
Steele, C. Jay ..... Atlanta, Ga.
Steele, James E. ..... Beaumont, Tex.
Steele, Robert A., Jr. ..... Corpus Christi, Tex.
Steeves, Arthur F. ..... New London, Conn.
Steffan, Robert F. ..... Los Angeles, Calif.
Steffens, Martin L. ..... Oklahoma City, Okla.
Stegner, A. L. ..... Houston, Tex.
Stein, Walter F. G. ..... Pampa, Tex.
Steinbach, G. R. ..... Alhambra, Calif.
Steinberger, Chester ..... Houston, Tex.

Steiner, Robert H. Mertztown, Pa.
Steinhauff, Frederick P. ..... Houston, Tex.
Stelzer, James G. ..... Jackson, Mich.
Stephan, Dean E. ..... Los Angeles, Calif.
Stephens, E. H. ..... Wichita, Kan.
Stephens, Lloyd W. ..... Fayetteville, Ark.
Stephens, O. V., Jr. ..... Houston, Tex.
Stephens, Robert A. Easton, Pa.
Stephens, Roy K. ..... Los Angeles, Calif.
Stephens, Thomas O. ..... Dallas, Tex.
Stephens, William H. ..... Irvington, N. J.
Stephenson, G. W. ..... Corpus Christi, Tex.
Stephenson, James F. ..... Houston, Tex.
Stephenson, R. B. ..... Dayton, Ohio
†Stepp, V. E. ..... Dallas, Tex.
Stericker, William ..... Upper Darby, Pa.
Stern, Milton ..... Cambridge, Mass.
Sterne, Cecil M. ..... Long Island City, N. Y.
Sterrett, Elton ..... Houston, Tex.
Stetson, Richard W. ..... New York, N. Y.
Stevens, Chapin E. ..... New York, N. Y.
Stevens, Ward W. Monroe, La.
Stevenson, John M. ..... Dallas, Tex.
†Stewart, Alex ..... New York, N. Y.
Stewart, C. A. ..... New Orleans, La.
Stewart, Edwin L. ..... New York, N. Y.
Stewart, Isaac New York, N. Y.
Stewart, W. Fred Tulsa, Okla.
Stewart, W. H. ..... Beaumont, Tex.
Stiers, Vernon E. ..... Beaverton, Ore.
Stillwell, W. Ralph ..... Chicago, Ill.
Stirling, J. C. ..... Tulsa, Okla.
Stitt, James R. ..... Detroit, Mich.
Stobaugh, Robert B., Jr. ..... New York, N. Y.
†Stobbs, Henry A. ..... Wheeling, W. Va.
Stobie, John J., Jr. ..... Chicago, Ill.
Stockdale, Harold L. ..... Houston, Tex.
Stodalka, Allan A. ..... Calgary, Alberta, Canada
Stoddard, Edgar S. ..... Chicago, Ill.
Stoertz, Howard Philadelphia, Pa.
Stokes, James H. ..... Houston, Tex.
Stokes, William S. ..... Huntington, Park, Calif.
Stone, J. M. ..... Wilmington, Del.
Stone, William J. ..... Kansas City, Mo.
Storer, Alton B. ..... Kansas City, Mo.
Storm, Arthur E. ..... Associated, Calif.
Story, E. B. ..... Ambridge, Pa.
Stose, Harold F. ..... Conshohocken, Pa.
†Stott, Tom ..... Morton Grove, Ill.
Stoutland, Arnold ..... Berkeley, Calif.
Strachan, John F. ..... London, England
Strader, William P. ..... Dayton, Ohio
Strain, Marrette ..... Ridgefield Park, N. J.
Strauss, Leon, Jr. ..... Boston, Mass.
Strawderman, Harold P. ..... Long Beach, Calif.
Strawn, Lynn Rudolph ..... Port Neches, Tex.
Streetman, George B. ..... Port Neches, Tex.
Streever, Otis J. ..... Newport News, Virginia
Streicher, Lee ..... Laverne, Calif.
†Streit, Frank H. ..... Columbus, Ohio
Strickland, Henry R. ..... San Francisco, Calif.
Strobl, Lee J. ..... Los Angeles, Calif.
Strole, Leo J. ..... Monroe, La.
Strom, C. F. ..... Newark, N. J.
Stromsoe, Douglas A. ..... Azusa, Calif.
Strothman, Harry N. ..... Blawnox, Pa.
Stuart, Jack L. ..... Dallas, Tex.
Stuart, Linden, Jr. ..... Kenilworth, N. J.

†Stubbs, F. J. ..... Edmonton, Alberta, Canada
Stubbs, Thomas L. ..... Montreal, Queb., Canada
Stuber, Herbert D. ..... Midland, Mich.
†Stull, Fred D. ..... Owensboro, Ky.
Sturrock, Murray G. ..... Pittsburgh, Pa.
Stutzman, Milo J. ..... Kansas City, Mo.
Sudduth, Lamar F. ..... Midland, Tex.
Sudrabin, Leon P. ..... Newark, N. J.
Sullender, Maurice C. ..... Pasadena, Tex.
Sullivan, E. H. ..... Shreveport, La.
Sullivan, Harry Ivan ..... Phoenix, Ariz.
Sullivan, Jean H. ..... Dallas, Tex.
Sullivan, M. N. ..... Harvey, La.
Summerson, Thomas J. ..... Spokane, Wash.
Sundberg, Jack O. ..... Coalville, Utah
Sussman, Sidney ..... New York, N. Y.
Suverkrop, E. A. ..... Trenton, N. J.
Svrchek, Joseph G. ..... Chicago, Ill.
Sverkerson, William C. ..... Minneapolis, Minn.
Svetlik, Joseph ..... Hammond, Indiana
Swaim, Earl ..... Chicago, Ill.
Swanbeck, Leonard W. ..... St. Jacob, Ill.
†Swann, J. S. ..... Hammond, Ind.
Sward, G. G. ..... Washington, D. C.
†Swartout, C. W. ..... St. Louis, Mo.
Sway, Boris ..... Cincinnati, Ohio
Sweet, Warren W. ..... Jersey City, N. J.
Swensson, Stuart J. ..... Pittsburgh, Pa.
Swift, John ..... Cambridge, Mass.
Swindoll, Robert E. ..... Jackson, Miss.

T

Tait, Emmitte P. ..... Atlanta, Ga.
Tallant, Ralph K. ..... Florence, Ala.
Talley, Royal N. ..... Los Angeles, Calif.
†Talmey, Paul ..... Chicago, Ill.
Tanaka, Michio ..... Osaka, Japan
Tandy, Edward H. ..... El Segundo, Calif.
Tanner, Jack N. ..... Niagara Falls, Ont., Canada
Tarquinee, Val ..... New York, N. Y.
Tator, Kenneth ..... Coraopolis, Pa.
Tatum, Joe F. ..... Hattiesburg, Miss.
Tatum, John M. ..... Hattiesburg, Miss.
Taubman, Louis ..... Tulsa, Okla.
Taylor, Frank S. ..... Oklahoma City, Okla.
Taylor, Gerald D. ..... Shreveport, La.
Taylor, R. D. ..... New York, N. Y.
Taylor, William R. ..... Corpus Christi, Tex.
Teahan, James T. ..... Staten Island, N. Y.
Teale, Edward P. ..... Washington, D. C.
Teckoe, John E., Jr. ..... Windsor, Canada
Teel, Rodney B. ..... Wilmington, N. C.
Teeple, Herbert O. ..... New York, N. Y.
Temmerman, John A. ..... Rochester, N. Y.
Tenebaum, Martin J. ..... Milwaukee, Wis.
Terrill, J. Mark ..... Wilmette, Ill.
Terry, Fred P. ..... Oakland, Calif.
Thalmann, E. H. ..... New York, N. Y.
Thatcher, Fred G. ..... Las Piedras, Venezuela
Thayr, Starr ..... Houston, Tex.
Thelen, Floyd E. ..... Chicago, Ill.
Thibodaux, Paul T., Jr. ..... Tulsa, Okla.
Thiede, Richard Conrad ..... Grasselli, N. J.
Thiele, Alfred W. ..... St. Louis, Mo.
†Thies, H. R. ..... Akron, Ohio
†Thistle, James F. ..... Ashland, Ky.
†Thomas, Arba ..... Middletown, Ohio
Thomas, Beaumont ..... Watertown, N. Y.
Thomas, Charles C. ..... Pittsburgh, Pa.
Thomas, J. Bosley ..... Baltimore, Md.
Thomas, J. F. J. ..... Ottawa, Canada
Thomas, Paul D. ..... New York, N. Y.
Thomas, Ralph W. ..... Waukesha, Wis.
Thompson, David H. ..... Waterbury, Conn.
Thompson, Frank C. ..... Houston, Tex.
Thompson, George M. ..... Houston, Tex.
Thompson, Harris ..... Chicago, Ill.
Thompson, Harvey W. ..... London, Ont., Canada
Thompson, John G. ..... Washington, D. C.
†Thompson, R. W. ..... Big Springs, Tex.
Thompson, Roy T. ..... Houston, Tex.
Thompson, Thomas F., Jr. ..... St. Petersburg, Fla.
Thomson, J. B. ..... Big Rapids, Mich.
Thorley, Thomas J. ..... Long Beach, Calif.
†Thornberg, Joseph E. ..... Niagara Falls, N. Y.
Thorne, Anthony Z. ..... Maywood, N. J.
Thorngren, B. I. ..... Houston, Tex.
Thornhill, W. H. T. ..... Westfield, N. J.
Thornton, Bryan W. ..... Brooklyn, N. Y.
Thornton, J. A., Jr. ..... Cleveland, Ohio
Thornton, William M. ..... Dallas, Tex.
Thorpe, Vincent A. ..... Freeport, Tex.
Thurber, Walter P. ..... New York, N. Y.
Thurman, R. G. ..... Maumee, Ohio
Tibbetts, E. F. ..... North Quincy, Mass.
Tice, E. Allen ..... New York, N. Y.
Tietze, I. B. ..... Bartlesville, Okla.
Timberlake, Philip S. ..... Birmingham, Ala.
Timm, Lyle A. ..... Wyandotte, Mich.
Tinkleberg, Nelson ..... Kalamazoo, Mich.
Tinney, Thomas B. ..... Philadelphia, Pa.
Tipps, Charles W. ..... San Antonio, Tex.
Tisdale, O. R. ..... Houston, Tex.
Tissot, Robert A. ..... Wooster, Ohio
Titsworth, Edwin J. ..... Boston, Mass.
Titterington, Y. W. ..... Tulsa, Okla.
Tobin, H. H. ..... Aurora, Ill.
Todd, Raymond W., Jr. ..... Chicago, Ill.
Todhunter, Harold A. ..... Los Angeles, Calif.
Tompkins, Albert H., Jr. ..... Los Angeles, Calif.
*Toner, Daniel F. ..... Norman, Okla.
Toolan, Francis P. ..... New Orleans, La.
Toomey, Joseph C. ..... East Rochester, N. Y.
Torrans, David J. ..... Wilmington, Del.
*Totah, Nadim P. ..... China Lake, Calif.
Tour, Sam ..... New York, N. Y.
Towne, Robert L. ..... Caracas, Venezuela
Townsend, Edward M. ..... Linden, N. J.
Tracey, Edward J. J., Jr. ..... State College, Pa.
Tracy, Arthur W. ..... Waterbury, Conn.
Tragardh, Uno ..... Stockholm, Sweden
Trapp, Raymond F. ..... Hapeville, Ga.
†Treichler, H. E. ..... Newgulf, Tex.
Trela, Edward ..... Cleveland, Ohio
Treseder, Richard S. ..... Emeryville, Calif.
Trilsch, John D. ..... Houston, Tex.
Trimbur, William ..... Clifton Heights, Pa.
Tripler, Arch B., Jr. ..... Columbus, Ohio
†Trishman, L. E. ..... Ambridge, Pa.
Trissal, J. M. ..... Chicago, Ill.
Trivison, Lee M. ..... Cleveland, Ohio
Troiani, Francis ..... Vallejo, Calif.
Trop, Donald C. ..... Dayton, Ohio
†Troseth, Ralph ..... Midland, Tex.
Trouard, Sidney E. ..... New Orleans, La.
Troupe, Ralph A. ..... Akron, Ohio
Trout, H. E., Jr. ..... Glenshaw, Pa.
Trueblood, Howard M. ..... Dobbs Ferry, N. Y.
Truitt, James K. ..... Beacon, N. Y.
Truitt, W. O. ..... El Segundo, Calif.
Trumpour, Hermon B. ..... Buffalo, N. Y.
Tschudi, Traugott ..... Long Island City, N. Y.
Tucker, Billie E. ..... Beaumont, Tex.
Tucker, Sydney ..... Oswego, N. Y.
Tuckwiller, Donald Watts ..... Charleston, W. Va.
Tuggle, Layton C. ..... Pasadena, Tex.
Tuggle, Ray ..... Lafayette, La.
Tuhy, Mirko J. ..... Fanwood, N. J.
Tull, Walter T. ..... Longview, Tex.
Tully, Thomas J. ..... Rensselaer, N. Y.
Tundermann, Werner O. ..... Rahway, N. J.
Tune, Newell W. ..... Los Angeles, Calif.
Tupholme, Charles B. ..... North Sheffield, England
Turner, C. D. ..... Philadelphia, Pa.
Turner, Delber W. ..... Houston, Tex.
Turner, Elmer A. ..... Malden, Mass.
*Turner, Guy C. ..... Houston, Tex.
Turpin, Thomas O., Jr. ..... Independence, Kan.
Tuthill, Arthur H. ..... Wilmington, Del.
Tuttle, Loren W. ..... Bellwood, Ill.
Tweedle, Lloyd S. ..... Hamilton, Ont., Canada
Twidwell, Ralph W. ..... Tulsa, Okla.
Tyler, John C., Jr. ..... Houston, Tex.
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U

*Uhen, Robert F. ..... Milwaukee, Wis.
Uher, Joseph F. ..... Cleveland, Ohio
Uhlig, H. H. ..... Cambridge, Mass.
Uhr, Robert J. ..... New Braunfels, Tex.
Ullrich, A. H. ..... Austin, Tex.
Underwood, Charles F. ..... Aliquippa, Pa.
Underwood, O. G. ..... Chicago, Ill.
Unerfusser, John F. ..... Lake Jackson, Tex.
Unger, Julian H. ..... Houston, Tex.
Unger, Lewis C. ..... Boston, Mass.
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Upton, Paul H. ..... Yazoo City, Miss.
Urbanek, Joseph P. ..... Washington, D. C.
Urian, James H. ..... Marcus Hook, Pa.
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Vago, Stephen A. ..... Cincinnati, Ohio
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Valentine, Ralph J. ..... Pearl River, N. Y.
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Whitney, Roy P. Appleton, Wis.
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Wickman, Emil E.
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Wiebe, Richard Peoria, Ill.
Wiegers, Conrad L.
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Wieland, Rita Emeryville, Calif.
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Wilcox, Walter
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Wilkins, C. Edwin Kokomo, Ind.
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Williams, Leonard W.
Birchrunville, Pa.
Williams, Luther F.
San Francisco, Calif.
Williams, Raymond J.
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Williams, Robert D.
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Williams, Robert W.
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Williams, Sanders A.
Baltimore, Md.
Williams, Thomas P.
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†Williamson, T. D., Jr.
Tulsa, Okla.
Williamson, Theodore
Dallas, Tex.
Willis, Stanley J.
Minneapolis, Minn.
Willson, B. F.
Edmonton, Alberta, Canada
Willson, Keith E. Tulsa, Okla.
†Wilmoth, E. G. Enid, Okla.
Wilson, Bert Irving, Tex.
Wilson, Charles H. Houston, Tex.
†Wilson, D. W. Cleveland, Ohio
Wilson, Edwin L. Chicago, Ill.
Wilson, Fred Morgan City, La.
Wilson, Fred V. Port Arthur, Tex.
Wilson, J. B. St. Louis, Mo.
Wilson, J. Wright, Jr.
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Wilson, John R. McKeesport, Pa.
Wilson, L. Alexander
Marcus Hook, Pa.
Wilson, Norman D. Ankeny, Iowa
Wilson, Robert C. Akron, Ohio
Wilson, Rushen A.
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Wilson, T. A. Farmington, N. M.
Wilson, T. C.
East Chicago, Ind.
Wilten, Harry M.
Port Arthur, Tex.
Wimer, Charlton J. Dallas, Tex.
Winchester, Charles L.
Brooklyn, N. Y.
Winchester, Charles T.
Akron, Ohio
Windsor, John B.
Fairmont, W. Va.
Winegartner, E. C. Baytown, Tex.
Wing, Paul A. Wilmington, Calif.
Winham, E. S. Houston, Tex.
Winn, Harry M. Wilmington, Del.
Winn, James H. Shreveport, La.
*Winneberger, Ted W.
Oklahoma City, Okla.
†Winters, B. W. Atlanta, Ga.
Winters, Robert K. Lafayette, La.
Wintle, James V., Jr.
Sundown, Tex.
†Wirene, W. A. Schenectady, N. Y.
Wirstrom, Nils A.
New Orleans, La.
Wischhusen, John Cleveland, Ohio
Wisdom, James A. Van, Tex.
Wise, John J. Shreveport, La.
Wise, Robert S. Chicago, Ill.
Wiseman, Patrick L.
Drexel Hill, Pa.
Witheford, John M.
Stamford, Conn.
Withers, Frank P. Chicago, Ill.
Witt, J. Leslie Houston, Tex.
Wogan, Philip B. Westwego, La.
Woicik, Stanley J.
New York, N. Y.
Wolf, Edgar F. Baltimore, Md.
Wolfe, Wade, Jr.
Niagara Falls, N. Y.
Wollaston, F. O.
Vancouver, B. C., Canada
Wood, B. Nealley Portland, Ore.
Wood, Elgean I. Houston, Tex.
Wood, F. M. Houston, Tex.
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Wood, Herschel J. Houston, Tex.
Wood, R. L. Cincinnati, Ohio
Wood, William A., Jr.
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Woodruff, Warren E.
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Woods, Eldro M.
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Woodward, H. F., Jr.
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Woody, Charles L. Houston, Tex.
Woofter, Robert A.
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Woolford, Custis S., Jr.
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Worden, Eugene T.
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Works, George A., Jr.
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Worth, John S. Bethlehem, Pa.
Wray, T. Cecil Nashville, Tenn.
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Wright, Gordon R.
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Wright, Herbert J.
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Wright, Howard P.
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Wright, L. Lavelle
New Orleans, La.
Wright, Lewis S. Ashland, Ky.
Wright, Nathan E. Beaumont, Tex.
Wright, Preston C.
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Wyche, Ernest H. Coraopolis, Pa.
Wyder, Carl G. New York, N. Y.
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Wyman, John D.
Lake Charles, La.
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Y

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Zandona, Oliver J. Ashland, Ky.
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Zastrow, Orville W.
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Zeh, Henry P. Richmond, Calif.
Zeilberger, Ernest J.
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Alabama — Arizona — Arkansas — California

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POOLE, James E., Keystone Asphalt Products Co., 101 E. Ontario.
PREECE, Robert N., Rheem Manufacturing Co., 7600 S. Kedzie Ave.
PROSSER, Robert A., Duriron Co., Inc., 208 So. La Salle St.
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ROSE, Phillip E., 6930 S. Shore Dr.
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MT. CARMEL

KENEIPP, Richard L., Jr., Keneipp Contracting Co., R. R. 2.

MURPHYSBORO

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NORTHBROOK

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KLUMB, George H., Culligan, Inc.
SCHULZE, Robert E., Culligan Zeolite Co.

OAK LAWN

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KAUFFMAN, David S., Sinclair Pipe Line Co., Products Lines, Sinclair Bldg.
LADD, Glenn L., Sinclair Pipe Line Co., Sinclair Bldg.
MEYER, Robert H., Sinclair Pipe Line Co., Sinclair Bldg.
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FLINT

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HIGHLAND PARK

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BROOKES, A. Sidney, Public Service Electric & Gas Co., 80 Park Pl.
CLERMONT, William L., Public Service Electric & Gas Co., 80 Park Pl.
HULL, George C., Jr., Anglo-American Varnish Co., 55 Johnson St.
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STRAIN, Marrette, Continental Paper Co., Industrial Ave.

RIDGEWOOD

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GREAT NECK

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LAWTON, Ledra M., Harrison Radiator Div., General Motors Corp., Washburn.
ROGERS, Philip S., Harrison Radiator Div., General Motors Corp.

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FRIEDMAN, Charles, Paragon Paint & Varnish Corp., 5-49 46 Ave.
GERBEN, Max, Gerben Contracting Co., Inc., 36-11 Ditmars Blvd.
GRUBER, K. A., Chemical Fire & Rust Proofing Corp., 11-33 31st Dr.
INGHAM, Herbert S., Metallizing Engineering Co., Inc., 38-14 30th St.
KNAPP, Alfred P., Knapp Mills, Inc., 23-15 Borden Ave.
LESSUCK, Bertram, Metallizing Engineering Co., 38-14 30th St.
McWATERS, R. J., Metallizing Engineering Co., 38-14 30th St.
PETERKIN, Don W., Metallizing Engineering Co., Inc., 38-14 30th St.
POWER, Pierce H., Paragon Paint & Varnish Corp., 5-49 46th Ave.
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ALTENBURG, Charles J., Gibbs & Cox Inc., 21 West St.
ANDERSON, Harry A., Hills McCanna Co., 30 Church St.
ANDREW, Harold O., Moore-Publishing Co., Inc., 48 W. 38th St.
ANSON, E. H., Gibbs & Hill, Inc., 491 Pennsylvania Station.
AYRES, Robert F., Oakite Products, Inc., 19 Rector St.
BAGNELL, William E., Ebasco Services, Inc., 2 Rector St.
BAILEY, Clark A., Johns-Manville Sales Corp., 22 E. 40th St.
BALDWIN, L. A., Johns-Manville Sales Corp., 22 E. 40th St.
BARRON, Donald W., Albert F. Ganz, Inc., 511 Fifth Ave.
BATTLE, Thomas J., Joseph Dixon Crucible Co., Jersey City, N. J. For mail: 629 West 115th St.
BEADELL, Donald A., General Aniline and Film Corp., 435 Hudson St.
BEBBINGTON, Marguerite, International Nickel Co., Inc., 67 Wall St.
BECK, Walter, Lehigh University, 780 Riverside Dr.
BECKER, Wm. D., Burns & Roe, Inc., 233 Broadway.
BERENS, Philip E., Atlas Mineral Products Co., 475 Fifth Ave.
BLACK, Wm. Ralston, Koppers Co., Tar Products Div., Empire State Bldg.

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BOYD, George E., Koppers Co., Inc., 350 Fifth Ave.
BOYLAN, Francis M., Anderson-Prichard Oil Corp., 420 Lexington Ave.
BRADFIELD, George K., Jr., American Car & Foundry Co., 30 Church.
BREMER, Clarence, Oakite Products, Inc., 22 Thames St.
BRITTON, H. B., Trans-Arabian Pipe Line Co., 505 Park Ave.
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BUENSOD, A. C., Buensod-Stacey, Inc., 60 E. 42nd St.
CARPENTER, Howard B., Esso Standard Oil Co., 15 West 51st St.
COLE, Frank H., Walworth Co., 60 East 42nd St.
COLLINS, Walter F., New York Central System, 466 Lexington Ave.
CORDOVI, Marcel A., Babcock & Wilcox Co., 161 East 42nd St.
COURT, W. F., Shell Oil Co., Inc., 50 West 50th St.
COWART, B. C., Barrett Div., Allied Chem. & Dye Corp., 40 Rector St.
COYLE, T. G., United Chromium, Inc., 100 East 42nd St.
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CROWLEY, Edward J., Alox Corp., 70 Pine St.
DANSER, John W., American Telephone & Telegraph Co., 185 Broadway.
DANTZ, Thomas M., c/o The Ruberoid Co., 500 Fifth Ave.
DAVIS, Russell L., California-Texas Oil Co., 551 5th Ave.
DAW, Ronald F., The Texas Co., 135 East 42nd St.
DE LASKI, Robert D., Pittsburgh Coke & Chemical Co., 350 5th Ave.
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DEMPSEY, John M., Jr., States Marine Corp., 90 Broad St.
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SCHWAB, Carl M., Otis Pressure Control, Inc., Box 7206.
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SHOEMAKER, Raymond T., Oil Well Supply Co., 2001 N. Lamar.
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SLOVER, Charles L., Reilly Tar & Chemical Corp., 2523 McKinney.
SMITH, Tracy E., National Tank Co., 1101 Magnolia Bldg.
SPALDING, James C., Jr., Sun Oil Co., Box 2880.
STARBIRD, L. C., Southwestern Bell Telephone Co., 308 S. Akard St.
STATHAM, Tom R., Magnolia Pipe Line Co., Box 900.
STEPHENS, Thomas O., Amercoat Corp., 1227 Levee St.
STEPP, V. E., The Atlantic Refining Co., Prod. Div., Box 2819.
STEVENSON, John M., Youngstown Sheet & Tube Co., 610 Continental Bldg.
STUART, Jack L., Sola Catalytic Co., 520 Browder.
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DEVINE

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DUMAS

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CLAY, J. A., Jr., Service Engineers, Inc., Box 11068.
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DAVIS, J. E., Sr., Tnemec Co., Inc., Kansas City, Mo. For mail P. O. Box 7125, Sylvania Station.
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EGAN, James F., Texas Utilities Service Co., Box 1872.
FENWICK, Dick T., Southern Production Co., Inc., Box 670.
FISHER, Max C., Southwestern Bell Telephone Co., T & P Bldg.
FLEMING, Paul C., Gulf Oil Corp., Drawer 1290.
GUERNSEY, Richard L., Youngstown Sheet & Tube Co., 1807 Fair Bldg.
HARBISON, Dixon T., Harbison-Fischer Manufacturing Co., Box 64.
HESS, Fred E., Fred E. Hess, Inc., Ft. Worth National Bank Bldg.
HIBLER, Howard M., Lone Star Gas Co., 908-12 Monroe.
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JENNINGS, Carl H., The Texas Co., Box 1720.
JOHNSON, Gerald M., Sinclair Pipe Line Co., Fair Bldg.
LANDERS, Charles R., Service Pipe Line Co., 1820 Fair Bldg.
LIGON, John R., Sinclair Pipe Line Co., 901 Fair Bldg.
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MOSIER, Benjamin, Convair, Eng. Test Lab., Chemical Sec.
NOAH, John E., Sinclair Pipe Line Co., 901 Fair Bldg.
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SCOTT, Paul T., Convair, Eng. Test Lab., Chemical Sec.
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FREEPORT

ACKER, Voscoe, The Dow Chemical Co.
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JOHNSON, Robert T., Ethyl-Dow Chemical Co.
JORGENSEN, Roy C., Dow Chemical Co., Bldg. A-906.
LINDVEIT, G. M., The Dow Chemical Co.
McCUTCHEN, Charles W., The Dow Chemical Co., Bldg. A-906.
MUERY, Sam J., Jr., Freeport Sulphur Co., Drawer A.
MUSGROVE, Joe D., The Dow Chemical Co.
NEWPORT, John J., Electrochemical Eng. Dept., The Dow Chemical Co.
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SHIGLEY, C. M., The Dow Chemical Co.
THORPE, Vincent A., Ethyl-Dow Chemical Co.
VAN DUSEN, Glenn T., Jr., Freeport Sulphur Co., Drawer A.
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GALVESTON

BOYD, William G., Jr., Cotton Concentration Co., Inc., 4802 Alamo.
FARMER, Sidney C., Jr., Farmer's Marine Copper Works, Inc., 1816 Ave. C.
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GRAND SALINE

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HIGHLANDS

EDGAR, Lenville C., Tube-Kote, Inc., 709 N. Magnolia.

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ALLEN, Edward R., Jr., Humble Pipe Line Co., Rt. 7, Box 1400.
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BARROW, D. N., Delta Engineering Corp., Box 13027.
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BILLINGS, Thomas J., Thornhill-Craver Co., Box 1184.
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BLOOMQUIST, Charles T., Corrostops Co., Box 3049.
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BOND, Donald H., The Texas Pipe Line Co., Box 2332.
BOOTH, Robert C., Shell Oil Co. For mail: 5719 South Seas.
BOWMAN, William W., Armco Drainage & Metal Products, Inc., Box 1699.
BOYCE, Trevor G., Eclipse-Pioneer Div., Bendix Aviation Corp., Tetterboro, N. J. For mail: Box 9693.
BRANNON, R. A., Humble Pipe Line Co., Drawer 2220.
BRENDEL, Robert O., Crane Co., 2204 Pease Ave.
BRENNAN, Thomas J., Carpenter Steel Co., Union, N. J. For mail: 3220 Louisiana St.
BRESHEARS, Frank S., Jr., Great Southern Supply Co., Box 891.
BROCK, James R., Humble Pipe Line Co. For mail: 2158 Pelham.
BROOKS, Robert C., Cameron Iron Works, Inc., Box 1212.
BROUSSARD, Edward A., Gulf Refg. Co., Houston Pipe Line Div., Box 1203.
BROWN, Charles D., Aluminum Co. of America, 1806 Commerce Bldg.
BROYLES, Wayne E., Branche-Krachy Co., Inc. For mail: Box 18271.

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BRUDVIG, Lloyd A., Plastic Coating Corp., Box 13127.
BRUYERE, W. H., Pan American Pipe Line Co., Niels Esperson Bldg.
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BUCHANAN, William C., Rowan & Buchanan, Box 14035.
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CALDWELL, Joseph A., Humble Oil & Refining Co., Box 2180.
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CARROLL, David R., Humble Pipe Line Co., Corrosion Lab., Rt. 7, Box 1400.
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CHAVIGNY, Neil L., The Chavigny Co., 805 M&M Bldg.
CLARK, Hezzie, Humble Pipe Line Co., Drawer 2220.
CLEMENS, John J., The Dow Chemical Co., 2217 Commerce Bldg.
CONNELLY, Lewis B., Eastman Chemical Products, Inc., Kingsport, Tenn. For mail: State National Bldg.
CONNORS, William F., Humble Oil & Refining Co., Box 2180.
CONROY, John H., Rosson Richards Co., Box 8188.
COOK, Conrad J., Houston Porcelain Enameling Co., 1130 Sidco Rd.
CROWE, Raymond H., Transcontinental Gas Pipe Line Corp., Box 296.
CROWELL, J. G., Kuhn Paint Co., 4020 Center.
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DAVIS, Charles T., Jr., "The Pipeliner." For mail: 1621 Missouri.
DAVIS, Edward C., Jr., Western Industrial Maintenance, Inc., 2207 Nicholson.
DAVIS, Jack G., Transcontinental Gas Pipe Line Corp., Box 296.
DAVIS, L. Rex, Tuboscope, Box 8295.
DAWSON, R. A. J., Houston Equipment Co., Inc., 5513 Clinton Dr.
DAY, Stephen D., S. D. Day Co., 1973 W. Gray Ave., Box 13126.
DIAL, D. F., Jr., The Pure Oil Co., City National Bank.
DIXON, J. L., Non-Corrosive Prodts. Co. of Texas. For mail: 3755 Carlon St.
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DOREMUS, Gordon L., Cathodic Protection Service, 4601 Stanford.
DORR, Frank I., Jr., Trunkline Gas Co., Box 1642.
DRAGICS, Earl V., Owens-Corning Fiberglas Corp., 1114 Texas Ave.
DUESTERBERG, G. J., Plastic Applicators, Inc., Box 7631.
DULANEY, L. Bowen, Rosson-Richards Co., 1090 M&M Bldg.
EBBS, Edward L., Tidal Pipe Line Co., Box 1404.
EDWARDS, W. H., c/o The Superior Oil Co., 400 Oil & Gas Bldg.
ELLWOOD, Edward E., Reynolds Metals Co., Box 8176.
ESTEP, Quenton R., Humble Oil & Ref. Co., Box 2180.
EUTSLER, Eugene E., F. H. Maloney Co., Box 1777.
EVANS, Robert L., Jr., Houston Lighting & Power Co., Electric Bldg.
FANETT, H. M., United Gas Corp., Box 2628.
FARLEY, Elden R., Farley Co., Inc., 568 M&M Bldg.
FISCHER, H. E., Crown Central Pet. Corp., Box 1759.
FISCHER, Ivan M., South Chester Tube Co., 904 Esperson Bldg.
FISHER, Jack L., National Pipe Coatings of Texas, Inc., 4703 Fannin St.
FISHER, Ralph A., Kuhn Paint Co., 4119 Lehigh.
FITZGERALD, Charles L., Jr., Maintenance Engineering Corp., Box 2637.
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FRANK, Marion E., Tennessee Gas Transmission Co., Box 2511.
FUCHS, Fritz E., Aquaness Corp., 2005 Quitman.
FULLER, Carl T., Wolverine Tube Div., Calumet & Hecla, Inc.
GAIDO, S. J., Pipe Line Service Corp., Box 8188.
GARDINER, Peter, Plastic Applicators, Inc., Box 7631.
GARNER, Cordelle L., Tube Kote, Inc. For mail: 5214 Southlea St.
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GAY, John M., Associated Pipe Line Contractors, Box 2163.
GEDDES, Charles Albert, Jr., Cathodic Protection Service, 4601 Stanford St.
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GREER, Norman E., Norman E. Greer Co., Box 1311.
GREGG, Harris T., Metal Goods Corp., Box 1452.
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GRIFFITH, T. Ed., Tide Water Associated Oil Co., Box 1404.
GUINN, C. F., Tidal Pipe Line Co., Box 1404.
GUMM, Howard W., Industrial Gas Supply Corp., 1347 Munger.
GUMM, Warren G., Linde Air Products Co., 6110 Harrisburg.
HAAS, C. A., Wyatt Metal & Boiler Works, Box 3052.
HAGEMEIER, Charles E., Humble Oil & Refining Co., Box 2180.
HALL, George D., Thornhill-Craver Co., Inc., Box 1184.
HALLORAN, William D., Duriron Co., Inc., 682 M&M Bldg.
HANSEN, Eugene R., Plastics Applicators, Inc. For mail: 8025 Capitol St.
HANSON, Harry R., Humble Pipe Line Co., Box 2220.
HARLAN, John L., Humble Oil & Refining Co., (North Side Terminal), Box 2180.
HARRIS, Jack W., Cameron Iron Works, Inc., Box 1212.
HARTWICK, Otto J., Pittsburgh Plate Glass Co., Box 2555.
HEATLEY, David J., Kuhn Paint Co., 4020 Center.
HEINEN, Lawrence E., Tube-Kote, Inc., Box 20037.
HEITMAN, Talmage M., Jr., United Gas Corp., Box 2628.
HENRY, Ernest L., Crutcher-Rolfs-Cummings Inc., Box 2073.
HERBERG, William F., Jr., American Smelting & Refining Co., Box 2534.
HINKLE, George S., Jr., General Manufacturing Co. of Houston, Inc., 707 N. Drennan St.
HISKEY, C. G., Armco Drainage & Metal Products, Inc., Box 1699.
HOLEFKA, Theodore, Farley Co., 558 M&M Bldg.
HOLM, Emil G., Tube-Kote, Inc., Box 20037.
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HOPKINS, W. H., Tuboscope Co., Commerce Bldg.
HUESEMAN, Robert L., Middle West Coating & Supply, 3873 Wentworth.
HUGHES, David K., F. W. Gartner Co., 3805 Lamar Ave.
HULL, Tennyson J., III., National Association of Corrosion Engineers. For mail: 3615 Hastings St.
HYNES, Harold K., Mavor Kelly Co., M&M Bldg.
IRVING, Ralph, Vapor Honing Co., R. D. 1, Box 914.
JARED, John B., Jr., American Petroleum Co., Petroleum Bldg.
JASEK, Albert W., Humble Pipe Line Co., Drawer 2220.
JENKINS, Clark L., The Goodyear Tire & Rubber Co., Inc., Box 1678.
JOHNSON, Wayne A., Corrosion Rectifying Co., 1506 Zora.
JONES, Everett P., Texas Alloy Products Co., Box 19067.
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KELLEY, John V., The Texas Pipe Line Co. For mail: 712 Linder St.
KELLY, J. Dyche, Hydraulic Equipment Co., 2438 South Blvd.
KELLY, Thomas F. P., Mavor Kelly Co., M&M Bldg.
KELLY, Warner M., Otis Pressure Control, Inc., 2402 Broad St.
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LANE, H. S., Crown Central Petroleum Corp., Box 1759.
LAY, Albert F., Humble Oil & Refining Co., Box 2180.
LEDFORD, Robert C., Marine Gathering Co., The Oil & Gas Bldg.
LEE, E. G., Diamond Alkali Co., C & I Life Bldg.
LEMCKE, Ewald M., Hydrocarbon Construction Co., M&M Bldg.
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LOVOI, Frank J., Sinclair Refining Co., Box 2451.
LUGER, Karl E., K. E. Luger Co., Box 6704.
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MERCER, Kenneth K., L. E. Livingston & Son. For mail: 4023 Turnberry Circle.
MILLER, Jack C., United Centrifugal Pumps, West Bldg.
MILLER, Paul Thomas, The Texas Pipe Line Co. For mail: c/o R. B. Trow, Box 2332.
MILLING, Dan J., Kuhn Paint Co., 4020 Center.
MINER, Lucien L., Jr., Allen D. Stafford, Inc., 1814 Richmond Ave.
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MORGAN, Homer C., Gulf Oil Corp., Drawer 2100.
MORGAN, T. A., Gulf Coast Pipe Coating Corp., Box 2091.
MOSELEY, E. L., South Chester Tube Co., Esperson Bldg.
MUDD, O. C., Shell Pipe Line Corp., Box 2648.
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NELSON, F. M., Texas Gulf Sulphur Co., Second National Bank Bldg.
NORRIS, Lee, The Fish Engineering Corp., M&M Bldg.
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NOVAK, George W., Jr., Hughes Tool Co. For mail: 2622 Greenbriar.
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O'CONNOR, J. S., O'Connor & Co., 4101 San Jacinto.
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OWENS, Howell C., Coast Paint & Lacquer Co., Inc., Box 1113.
PARKER, Marshall E., Jr., Cormit Engineering Co. For mail: 2023 Jean St.
PARR, James M., Parkerizing, Inc. of Texas, Box 9286.
PARR, MacGregor A., Parkerizing, Inc. of Texas, Box 9286.
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RICHARDS, S. L., Jr., Rosson-Richards Co., M&M Bldg.
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RICHEY, Alvan E., Cathodic Protection Service, 4601 Stanford.
RIORDAN, Maurice A., Rio Engineering Co., 3607 Yoakum.
ROBINSON, Leonard, Jr., National Aluminate Corp., 1602 Vassar.
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ROSSON, J. H., Jr., Rosson-Richards Co., M&M Bldg.
ROTHROCK, E. S., Consolidated Chemical Industries, Inc., Mellie Esperson Bldg.
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SELLE, Joseph B., The Ohio Steel Foundry Co., Box 6125.
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SHEARON, Kervin B., Brance-Krachy Co., Inc., Box 1724.
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SHEPPARD, Lyle R., Shell Pipe Line Corp. For mail: 6522 Mercer St.
SHUGART, Brock, Pacific Valves, Inc. For mail: 5429 Hidalgo St.
SILBERSTEIN, Milton L., Soutex Technical Labs. For mail: 1607 Francis.
SIMPSON, A. D., Jr., United Gas Corp., Box 2628.
SLEDGE, B. L., Rice Institute, Box 322, West Hall.
SLINE, Louis, Sline Industrial Painters, 2162 Gulf Terminal Dr.
SMITH, Alonzo L., Petroleum Instrument Co., Box 6252.
SMITH, Carl M., Gulf Engineering Co., Inc., 1682 Ingeborg St.
SMITH, Robert M., Koppers Co., Inc. For mail: 3830 Marquette St.
SMITH, Sidney V., Napko Paint & Varnish Works, Box 9145.
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SNYDER, Kenneth T., Atlas Mineral Products Co. of Penna., Inc., Box 15034.
SPAFFORD, Perry Parker, Stanolind Oil & Gas Co., Box 3092.
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STEGNER, A. L., Tennessee Gas Transmission Co., Box 2511.
STEINBERGER, Chester, Pacific Valves, Inc., Long Beach, Calif. For mail: 1101 Sterling Bldg.
STEINHAUFF, Frederick P., Humble Oil & Refining Co., Box 2180.
STEPHENS, O. V., Jr., Brown & Root, Inc., 4100 Clinton Dr.
STEPHENSON, James F., Gulf Refg. Co., Pipe Line Div., Drawer 2100.
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STOKES, James H., Gulf Refining Co., Houston Pipe Line Div., Box 1203.
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THOMPSON, George M., Bettis Corp., Drawer 9365.
THOMPSON, Roy T., Tretolite Co., Box 2546.
THORNGREN, B. I., Maintenance Engr. Corp., Box 2637.
TISDALE, O. R., Tidal Pipe Line Co., Box 1404.
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